JOURNAL OF THE SOCIETY OF

MOTION PICTURE AND TELEVISION ENGINEERS

Screen Viewing Factors Symposium

Luminance Discrimination

Influence of Surround Color

Visual Performance at Low Brightness

Surround Brightness Factor

Photometric Factors

Relating Production to Exhibition

Screen Brightness Committee Report

High-Speed Light Source

Dynamic TV Transfer Characteristic

Filters in a TV Camera

Duplication of Color Images

American Standard

70th Semiannual Convention • October 15–19 • Hollywood

SEPTEMBER 1951

Society of Motion Picture and Television Engineers

JOURNAL **VOL. 57** **SEPTEMBER 1951** **NO. 3**

Subscription to nonmembers, $12.50 a year; to members, $6.25 a year, included in their annual membership dues; single copies, $1.50. Order from the Society's General Office. A 10% discount is allowed to accredited agencies on orders for subscriptions and single copies. Published monthly at Easton, Pa., by the Society of Motion Picture and Television Engineers, Inc. Publication Office, 20th & Northampton Sts., Easton, Pa. General and Editorial Office, 40 West 40th St., New York 18, N.Y. Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

PRINTED BY MACK PRINTING COMPANY, EASTON, PA.

Foreword
Symposium on Screen Viewing Factors

By W. W. LOZIER, *Chairman, Screen Brightness Committee*

THE SUBJECTIVE IMPRESSIONS received during the viewing of motion pictures are influenced by a great many factors. What the eye sees on the screen is the result not only of the conditions of the original scene, but also of the many steps of film processing and all the elements involved in the projection of the finished motion picture.

The Screen Brightness Committee has long been interested in the problem of establishing a scientific basis for determining preferred viewing conditions. The Committee sponsored a symposium on subjects pertaining to screen brightness at the Fall 1935 Convention of the Society. The record of this meeting, published in the May 1936 JOURNAL, summarized the state of knowledge at that time and served as the basis of formulation of a recommendation for projection screen brightness for 35-mm motion pictures. Technological developments since that time have greatly changed some of the basic factors involved. A summary of work done and current thinking on the problem of screen brightness was contained in a discussion prepared by F. J. Kolb, Jr., and published in the April 1951 JOURNAL. Subsequently, the Screen Brightness Committee sponsored the Screen Viewing Factors Symposium at the May 2nd session of the Spring Convention of the Society in New York this year. It is the conviction of the Screen Brightness Committee that the definition of the preferred conditions of viewing motion pictures is, in large measure, subject to scientific determination. The papers presented at the above-mentioned Symposium and published in the following pages are serious efforts and the first results of renewed activity in this direction.

E. M. Lowry, in his discussion of the luminance discrimination of the human eye, gives results of evaluation of the sensitivity of the eye, in this regard, as affected by the size and brightness level of the surrounding areas. MacAdam shows that the subjective impressions of hue and saturation are greatly influenced by the color quality of the surrounding light to which the eye is adapted. Critical levels of illumination, below which marked impairment of visual performance occurs, are indicated by Spragg in a study in a seemingly unrelated field which may, however, prove meaningful for motion picture viewing. Laboratory audience-preference studies by Guth relate preferred brightness levels of surrounding areas to the picture brightness. Logan, and Schlanger and Hoffberg present practical approaches to the prob-

lem of illumination of the areas surrounding the screen in a motion picture theater.

The "Report on Screen Brightness Committee Theater Survey" summarizes the results of measurement of screen brightness and related factors in 125 representative motion picture theaters in this country and in 18 West Coast review rooms used for viewing 35-mm motion pictures. The screen brightness for the majority of theaters is shown to be within or near the currently recommended standards, but there is a wide range of extreme values of brightness and other factors in a minority of the theaters which fall far outside the range of good projection practice.

It is the sincere hope of the Screen Brightness Committee that the papers reported in these pages will serve to stimulate many other worth-while technical studies on these subjects which will further assist in putting motion picture viewing on a scientific basis.

The Luminance Discrimination of the Human Eye

By E. M. LOWRY

Data are presented to show not only the effect of the luminance to which the eye is adapted on its ability to discriminate differences in luminance, but also the effect of the visual angle upon this important ocular function. That luminance discrimination depends upon whether the observer's attention is fixed upon a highlight or shadow region is shown by data on threshold luminance when scenes are being viewed in which the luminance varies over a wide range.

That the visual comfort of the audience in a motion picture theater has been of great interest for a long time is evidenced by the many papers on the subject of the projection screen and its surroundings, as well as by the activities of the Screen Brightness Committee of this Society. This interest arises in large part from the known fact that fatigue results when the eyes are used over extended periods in attempting to discern fine detail or to discriminate luminance differences when the luminance is so low that the visual system is working near its limit. As indicated by the title, this paper is concerned with the ability of the eye to discriminate differences in luminance. Its further purpose is to emphasize that, contrary to the often-accepted notion, the sensitivity of the human eye to luminance differences is much more affected by the luminance of the region immediately surrounding the point of attention than by the average luminance of the scene.

In the interest of clear understanding, some definition of terms is desirable. Throughout this paper, the word *luminance* is used in place of *brightness*.[1] The unit of luminance is the foot-Lambert[2] and is equal to the average luminance of a perfectly diffusing surface emitting or reflecting one lumen per square foot. That is to say, the average luminance in foot-Lamberts of any reflecting surface is the product of the illuminance in foot-candles by the reflectance of the surface.

Luminance discrimination or contrast sensitivity has been the subject of much investigation since the classical work of König and Brodhun some seventy years ago. A very large portion of the data collected has been under highly specialized conditions, such as a restricted field of view, low luminance surround, an

Communication No. 1412 from the Kodak Research Laboratories, a paper presented on May 2, 1951, at the Society's Convention, Screen Viewing Factors Symposium, at New York, by E. M. Lowry, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

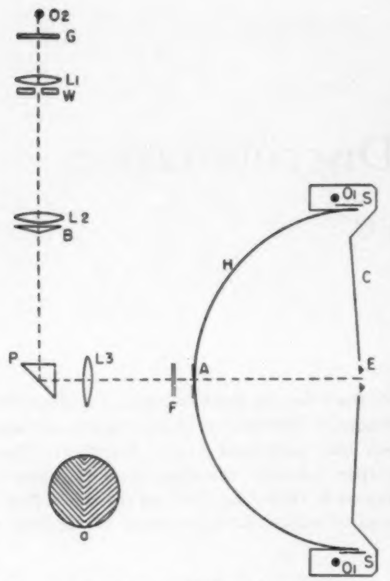


Fig. 1. Plan view of Visual Sensitometer.

artificial pupil, monocular viewing, etc. Such conditions have little, if any, resemblance to those which exist when an observer is viewing a scene; for example, a landscape out of doors. Normally he observes with both eyes, and the luminance may vary from nearly zero to thousands of foot-Lamberts. In addition, almost every scene presents to the eye a variegated pattern of color. Not only changes of light and shade exist, but also a gamut of many hues of varying saturation, as well as objects of manifold shapes and sizes. As an end result, the entire visual field is a complicated design made up of a host of variables, each of which may in some way affect the perceptions of the observer.

In an attempt to obtain numerical data under conditions simulating those of normal viewing, and yet provide adequate control of the factors of size of the visual field as well as of the test-spot luminance, and the luminance distribution in the surround, an instrument, which we have called a Visual Sensitometer, was constructed.

A plan view of this equipment is shown in Fig. 1. Here, H is a hemisphere one meter in diameter, with a conical-shaped cover, C. Both hemisphere and cover are painted inside with a matte white paint. At A is a test-field aperture of variable size and in the cover at E, a viewing aperture of sufficient diameter to permit placing the head of the subject in such a position that his visual field is almost 180°. The position of the observer's eyes with respect to the test aperture is fixed by means of a head and chin rest. Illumination of the sphere is accomplished by means of a ring of lamps, O_1, and the luminance of the sphere wall, that is, the surround or adapting field, is controlled by a ring-shaped shutter, S, which is adjustable over the gap between the rim of the sphere and the cover. With this arrangement, the luminance of the surround can be adjusted from zero to approximately 1000 ft-L.

Light from a biplane filament projection lamp, O_2, passes through the flashed opal glass, G, the lens, L_1, the neutral wedges, W, the lens, L_2, the biprism, B, the totally reflecting prism, P, the lens, L_3, the neutral filter, F, and the diaphragm, A, to the eyes of the observer at E. By means of this optical system, each eye of the observer views an aerial image of the biprism, B, in the form of a two-part field subtending an angle of 1.5° at the eye. The form of the field is shown in the insert at a. The luminance of the halves of this field is regulated by the neutral wedges at W, one of which can be adjusted by the person making observations.

In making a series of settings either for luminance match or for just-noticeable difference in luminance, the subject turns a knob which moves one of the wedges until he is satisfied that one field either matches or is just higher or lower in brightness than the other. An assistant records the wedge setting. While

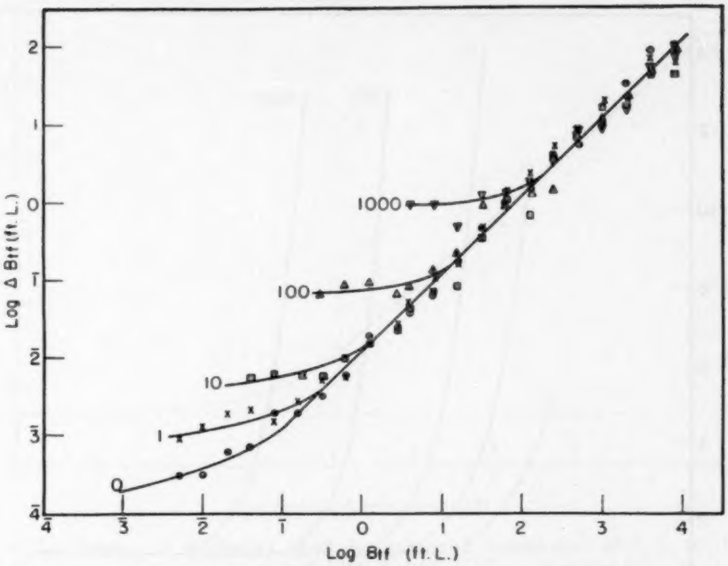


Fig. 2. Luminance discrimination, ΔB_{tf}, of the eye as a function of the test-field luminance, B_{tf}, in foot-Lamberts for surround luminances of 0, 1, 10, 100 and 1000 ft-L.

the method of just-noticeable difference was followed in the work reported in earlier papers,[3,4] a slight modification of that technique was adopted when securing the data presented here. Instead of setting for a just-perceptible difference between the two halves of the test field, the observer adjusted for equality of brightness and approached the balance point from each side. Five settings were made for each direction of approach to the balance point, and the average deviation from the mean was taken as a measure of the differential threshold, ΔB_{tf}. The symbol ΔB_{tf} is used to represent the difference in luminance between the two halves of the test field, which is just at the border line of discernibility. This method of securing the data seems to give the subject a little more confidence in reporting than when setting for least-perceptible difference, because it provides a somewhat more definite end point for his observations.

In Fig. 2 are shown the data obtained for a series of luminances of the conditioning field, and each point plotted represents the average of from three to five runs on different days for each surround luminance. Probably the most noticeable feature of these curves is that above a certain luminance of the test field the discrimination remains constant, regardless of the surround, and that the slope of the curve is very nearly 45°. This, of course, means that the much-discussed Fechner Fraction is also constant above this value. There is absolutely no indication from the data that the ability of the human eye to discriminate difference in luminance decreases even for values of the test field as high as 8000 ft-L. These results are in substantial agreement with those previously reported by the author[3] and by Jones.[4] Data by Steinhardt,[5] and by Craik[6] also demonstrate that contrast sensitivity remains constant even at the

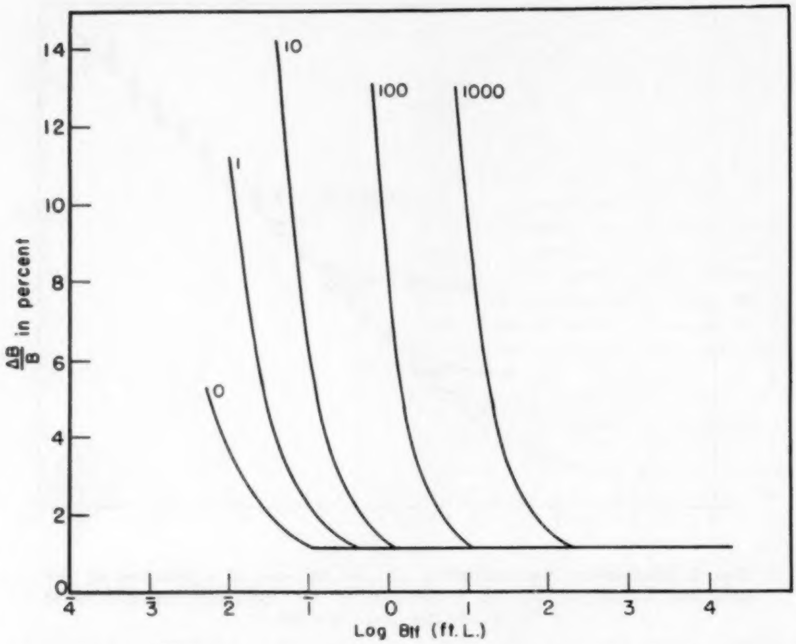


Fig. 3. Ratio of $\frac{\Delta B_{tf}}{B_{tf}}$, plotted as a function of log B_{tf} in foot-Lamberts for surround luminances of 0, 1, 10, 100 and 1000 ft-L.

highest values studied, which were approximately 10,000 and 4000 ft-L, respectively.

By means of a special optical system, an attempt was made to determine whether a sufficiently high luminance of the test field would reduce visual sensitivity for luminance differences. With this setup, a two-degree test field yielded a maximum luminance of approximately 32,000 ft-L, and, although rather persistent afterimages resulted, none of the observers participating in the test showed a decrease in his ability to detect a luminance difference of about 4%. In fact, each one reported that at the highest luminance the contrast was at least as apparent, if not more so, than at the lower ones. Although this test was more qualitative than quantitative, it seems safe to state that at luminances considerably above those encountered in any practical situation the visual mechanism retains its ability to distinguish a constant fractional difference in luminance.

The data shown in Fig. 2 have been replotted in Fig. 3 as the more familiar $\Delta B/B$ as a function of log B_{tf}. From the curves of this figure it will be seen that in the region of maximum luminance discrimination, represented by the flat portion of the curves, the ratio $\Delta B/B$ is just slightly over 1% and that this holds for test-field luminance above 0.3 ft-L for a dark surround. For higher values of surround luminance, namely, 1, 10, 100 and 1000 ft-L, the straight-line portion of the curves begins at correspondingly higher luminances of the test field.

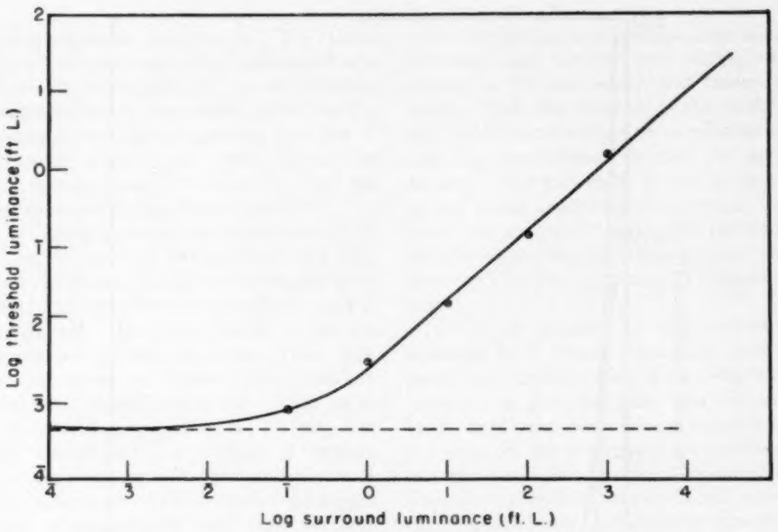


Fig. 4. Luminance of subjective black for surround luminances of 0, 1, 10, 100 and 1000 foot-L.

Subjective Black

Another aspect of the luminance discrimination of the eye which is of considerable importance is the luminance which will appear black. With the same equipment used in collecting data on contrast sensitivity, the visual threshold for luminance was determined with the same surround conditions as before, and the results are plotted in Fig. 4. As was the case with the differential threshold, so, with subjective black, the curve becomes linear above a surround luminance of approximately 1 ft-L, and has a slope of about 45 degrees. This means that for a surround higher than 1 ft-L, the luminance which will appear black is a constant fraction of that to which the eyes are adapted. As the conditioning luminance is reduced to zero, the values for subjective black approach the threshold for the dark-adapted eye, and the curve becomes asymptotic to the axis of abscissas.

Effect of the Size of the Surround on Threshold Luminance

While it is necessary to have information as to how the visual system responds to luminance and luminance differences, it is also important to know the effect of the size of the conditioning field on this function. For this purpose, a simple instrument called an "adaptometer" was built. It consisted of a brass tube 16 in. long and 1.5 in. in diameter, blackened both inside and out. In one end of the tube a small tungsten filament lamp was mounted behind a disk of flashed opal glass. In front of the opal glass was a black diaphragm with a 1-in. aperture which served both to limit the size of the field and to eliminate specular reflectance from the interior walls of the tube. By means of a long flexible wire cable, the lamp was connected to a 6-v storage battery through an ammeter, a rheostat, and a microswitch in the hands of the operator. The luminance of the opal

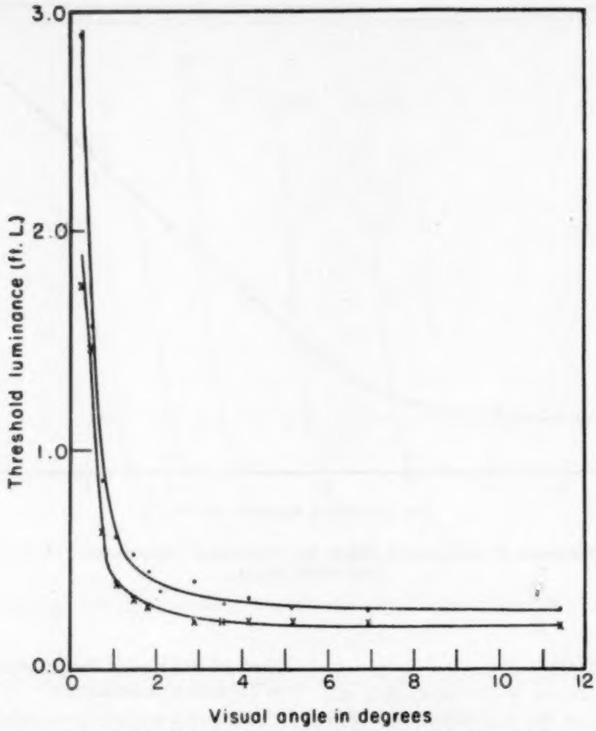


Fig. 5. Luminance of subjective black as a function of visual angle for constant surround luminance. ●—white target = 348 ft-L, gray rings 5.5 ft-L; x—white target = 211 ft-L, gray rings 3.2 ft-L.

glass in foot-Lamberts was measured for a series of filament currents, and a calibration curve of luminance as a function of current plotted.

For the purpose of making readings, the observer took up his station at a distance of 20 ft from the adaptometer. The instrument had previously been placed in line with the part of the scene to be investigated. Then, while viewing the opal glass, which at this distance subtended an angle of 15 min, through the open end of the blackened tube and against the background chosen, the observer adjusted the lamp current until by repeated interruptions of the current he could no longer distinguish a flashing of the light from the lamp. The luminance of the opal glass at the current for disappearance of the flashing light represented threshold luminance or subjective black. Of course, variation of the lamp current produced a change in the color of the light emitted, but, since the luminances were quite low, it was felt that this effect could be neglected. Furthermore, because of the small filament dimensions, there was little lag between current pulses and filament temperature on either making or breaking the circuit.

With this equipment set up behind a circular white target having a hole in the center to accommodate the end of the adaptometer tube, a series of threshold

determinations was made. The luminance of the target was maintained at a constant value, and a number of different-sized black rings were placed on the white background to present a variety of sizes of visual angle. The size of the white target was 12° at the eye, and the rings varied in size from 0.5 to 12°.

Measurements at two luminance levels (Fig. 5), namely, 348 ft-L and 211 ft-L, demonstrated that for visual angles over about 3° the effect on subjective black is negligible. In other words, it is the luminance of the object which lies close to the point of fixation that primarily controls visual sensitivity. This same effect has been reported by Wright[7] and by Crawford.[8] In studies of motion picture projection, Reeb[9] found that only the luminance of the center of the screen was of importance and that varying-sized areas of the picture had no effect on the ability of the eye to distinguish differences in screen luminance.

Threshold Luminance Under Field Conditions

So far, the results reported have been those obtained in the laboratory under controlled conditions. In order to test the visual response when viewing outdoor scenes, the adaptometer, mounted on a tripod, was carried to the location selected and set up so that it was viewed with the various points of interest in the scene as the immediate surround. For purposes of record and future experiments, a camera was placed at the observer's station and the scene photographed. Figures 6, 7 and 8 illustrate the instrument as used. The data printed on the figures show the luminance at the point indicated as well as the value obtained for subjective black. Up to the present, only a few scenes have been investigated, so that the data can be nothing more than indicative. They have been plotted in Fig. 9, together with the curve for the threshold taken from Fig. 4.

While at first sight there appears to be little correlation, and perhaps even some contradiction, between the values obtained in the laboratory and those resulting from observations in the field, a number of factors must be considered in drawing conclusions. It may be said, however, that the results do line up more or less in the order expected, that is, the lower the luminance of the area immediately surrounding the adaptometer, the lower will be the luminance of subjective black.

Visual phenomena as examined and reported by a large number of investigators have shown that what an observer perceives at any particular place in the visual field at a given time is dependent not only on the immediate stimulation, but also upon the preceding stimulation from the entire field and upon that from the region closely surrounding the test area. A part of the discrepancy, in the results reported here, is probably caused by the radical difference in the surrounds. In the laboratory, the adapting fields were uniform, while in actual scenes they were extremely nonuniform. Because of this lack of uniformity, the difference in completeness of adaptation for the particular area tested may well have been a contributing factor in the lack of agreement shown. It is very difficult to gaze steadily at a given point for two or three minutes until the eyes become thoroughly adapted to the luminance closely adjacent to the test field, and this is especially true when the surround consists of a complex pattern, such as is the case in the average outdoor scene. For the case of a uniform conditioning field, slight eye movements are not of great consequence, since the conditioning luminance remains constant. When a variable luminance is present, however, any slight shift in direction of view will result in a change of adaptation.

In the opinion of the writer, the chief value to be derived from the data taken in the field is their evidence as regards the difficulty of interpreting the results of

Fig. 6. Illustration of the use of the adaptometer for field work.

Fig. 7. Illustration of the use of the adaptometer for field work.

Fig. 8. Illustration of the use of the adaptometer for field work.

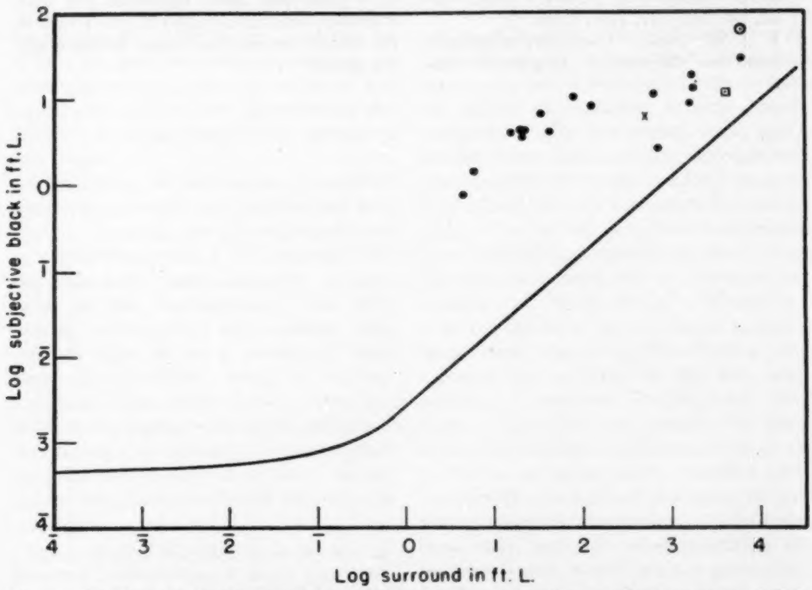


Fig. 9. Results obtained for subjective black when viewing outdoor scenes. Solid curve represents data taken in the laboratory.

x — from Fig. 6; ⊡ — from Fig. 7; ⊙ — from Fig. 8.

controlled experiments on visual function in terms of practical problems. Before this may be done satisfactorily, a great deal more information must be obtained on the actual viewing situation.

References

1. L. A. Jones, "Colorimetry: preliminary draft of a report on nomenclature and definitions," *J. Optical Soc. Am.*, vol. 27, pp. 207–213, June 1937.
2. *Illuminating Engineering Nomenclature and Photometric Standards*, Sec. 05.070, Illuminating Engineering Society, New York, 1942.
3. E. M. Lowry, "Some experiments with binocular and monocular vision," *J. Optical Soc. Am.*, vol. 18, pp. 29–40, Jan. 1929.
4. L. A. Jones, "Recent developments in the theory and practice of tone reproduction," *Phot. J.*, Sec. B, vol. 89B, pp. 126–151, Nov.-Dec. 1949.
5. J. Steinhardt, "Intensity discrimination in the human eye," *J. Gen. Physiol.*, vol. 20, pp. 185–209, Nov. 1936.
6. K. J. W. Craik, "The effect of adaptation on differential brightness discrimination," *J. Physiol. London*, vol. 92, pp. 406–421, May 1938.
7. W. D. Wright, *Researches on Normal and Defective Color Vision*, C. V. Mosby, St. Louis, Mo., 1947, pp. 230–231.
8. B. H. Crawford, "The effect of field size and pattern on the change of visual sensitivity with time," *Proc. Roy. Soc. London*, vol. 129B, pp. 94–106, June 1940.
9. O. Reeb, "A consideration of the screen brightness problem," *Jour. SMPE*, vol. 32, pp. 485–494, May 1939.

Discussion

Anon: Approximately how many subjects have you tested in each viewing situation?

E. M. Lowry: We've had, in all, five different subjects.

Anon: Did you get the impression that the results would have been much the same if you had used a great many more subjects?

Mr. Lowry: The curves might have been somewhat more smoothed out with a greater number of subjects, but I believe the results would have been substantially the same.

Influence of Color of Surround on Hue and Saturation

By DAVID L. MACADAM

Loci of constant hue are shown for daylight, tungsten light, and green and blue surrounds. Loci of constant saturation are shown for daylight and tungsten-light surrounds. The effects of field size and simultaneous contrast are also shown.

THE APPEARANCE of a projected color picture depends on the state of adaptation of the audience. This is governed by the picture itself, by its predecessors within the past few minutes, and, to an important extent, by the color of the light in the field of view surrounding the screen. This last factor is the subject of this paper.

The effects of adaptation to various surrounding colors are qualitatively well known. Usually the picture appears to be off balance, with a predominant hue approximately complementary to the color of the surroundings. For this reason, chromatic surroundings are frowned upon by some makers of color films. Furthermore, even a neutral surround, albeit rather low in intensity, stabilizes the adaptation of the audience and causes them to notice unintentional variations of balance in a film. In an almost completely darkened theater, the projected picture governs the adaptation of the audience so as to compensate, more or less completely, for accidental variations of balance. Any illumination of portions of the visual field near the screen provides a reference white, so that variations of balance become more noticeable. For this reason, some makers of color films strongly recommend that the light in the surroundings be kept to the bare minimum required for safety.

As other speakers in this symposium have indicated, considerably more than the statutory minimum is necessary for comfort and "good seeing." Therefore, it seems desirable to have some quantitative data concerning the effects of the color of the surround on the hues and saturations perceived in projected pictures. Such data may indicate the best colors for surrounding illumination, so as to obtain optimum safety, comfort and vision with minimum disturbance of the hues perceived in the picture. Adequate data may indicate some condition of balance which, paired with a particular quality of light in the surround, will cause the least perceptible effects for normally expected variations of balance and auditorium lighting.

Communication No. 1419 from the Kodak Research Laboratories, a paper presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by David L. MacAdam, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

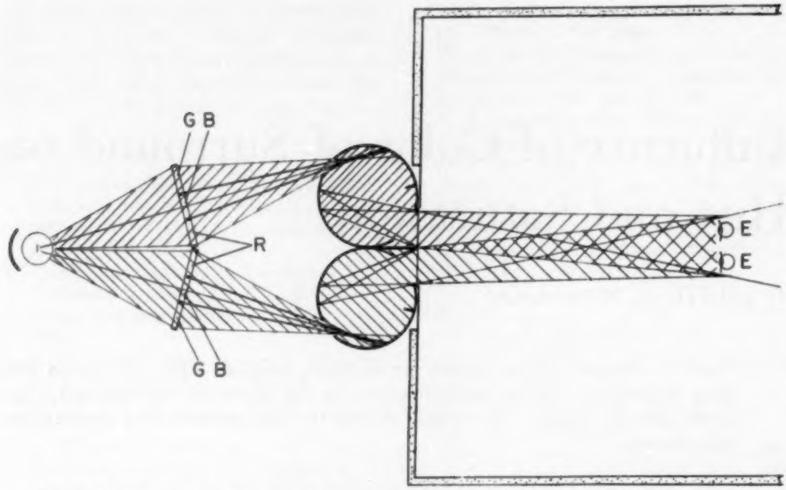


Fig. 1. Schematic diagram (horizontal cross section) of twin colorimeter, observing booth and observer's eyes.

To obtain and show such data, it is necessary to employ a method of measuring colors which is independent of variations of adaptation of the observer. With such a method, it is possible to determine the variations of measured colors which are required to produce equivalent effects under various conditions of adaptation.

A method, of the kind required for measuring colors and for representing the effects in which we are interested, was recommended in 1931 by the International Commission on Illumination. It was adopted by the American Standards Association as a War Emergency Standard in 1942, and within the last month has been reaffirmed as a regular American Standard.[1] The method has been described previously in this Journal.[2,3] The chromaticity diagram, which is commonly used to represent the results of color measurements, is very useful for representing and interpreting the results of quantitative research on color vision. Any color is always represented by a fixed point in the chromaticity diagram, regardless of the effects of adaptation in changing the perceptions arising from that color. This property of the chromaticity diagram implements the psychophysical definition of color[4] as "characteristics of light." These characteristics are independent of the state of adaptation of the observer. On the other hand, the chromatic attributes, hue and saturation, of the sensation resulting from any color, depend very much on the observer's state of adaptation. The coordinates of the point representing a color do not change, but hue and saturation do, when the color of the surround is changed.

The experimental arrangement used to get the desired data is indicated in Fig. 1. This is a horizontal cross section through a twin colorimeter, the observing room, and the observer's eyes.[5] The amounts of light passed by the red, green and blue filters, R, G, B, are varied by rectangular diaphragms, moved in vertical slots by remote control. These beams are mixed in the interiors of two hollow white spheres. The blended light within the spheres is viewed through portions of two plastic Fresnel lenses.

They appear as two adjacent semicircles. They are surrounded by a fluorescent cloth which glows with light of whatever color is desired. The cloth is irradiated with ultraviolet energy, which excites the surround but does not contaminate the colors of the light in the central field.

Figure 2 shows series of points in the chromaticity diagram. Each series represents colors of various saturations, all of which appear to have the same hue when seen with a black surround. The point W represents the color which appears to be white when no other colors are visible. The innermost point on each curve represents the color which appears to be white when the adjacent semicircle has the color represented by the outermost point. The differences between W and the innermost points, therefore, represent the effects of simultaneous contrast, and indicate possible effects of various colors in a picture on the appearance of neighboring colors in the picture.

Figure 3 shows series of colors which appear to have constant hue when surrounded by light matching the chromaticity of a blackbody at 3200 K. These curves are entirely different from the preceding ones. Their center of convergence represents a color that appears white when seen alone in such surroundings. The innermost point on each curve represents the color that appears white in such a surround, when seen side by side with the saturated color represented by the outermost point. Figure 4 shows the constant-hue series and the effects of simultaneous contrast in a blue surround, the color of which is indicated by the cross. Figure 5 shows constant-hue curves and the effects of simultaneous contrast when the general surround is green.

The preceding results were obtained with a test field subtending 12°. Figure 6 shows results obtained with a test field subtending 2°, with a surround only slightly greenish compared to daylight. In this case, hues particularly easy to remember were chosen. Thus, the yellow was neither greenish nor reddish, and the purple was not predominantly bluish nor reddish. The innermost extremity of each curve again represents the color which appeared white in one semicircle, when the saturated color represented by the outer extremity was in the adjacent semicircle.

The oval curve represents a series of colors of various hues but equal saturation, as judged by comparing neighboring hues in the 2° field.[6] These comparisons were begun at yellow and progressed through orange, red, purple, blue and green, back to yellow. The sequence was then reversed, with results which verified quite closely the results of the first sequence. The circle near the center represents the color of the surround, which at all times appeared as an acceptable white.

Figure 7 shows similar results for the same hues, and for constant saturation, with a surround nearly matching the color of a 3200 K blackbody light source. The results for the two different colors of surround are compared in Fig. 8. The saturations corresponding to the constant-saturation ovals were not necessarily equal in the two surrounds.

Very few data of the kind shown here have been published. Bouma and Kruithof[7] identified sets of colors which appeared to have the same hues in several surrounds. They did not determine constant-hue loci, estimate the saturations of their colors, or evaluate the effects of simultaneous contrast. As a matter of fact, they assumed the constant-hue loci to be straight lines radiating from the point representing the surround, and they drew far-reaching conclusions from extrapolations based on that assumption.

Newhall, Nickerson and Judd[8] published curves of constant hue and saturation derived from observations of Munsell paper samples in daylight. Helson and Grove[9] studied the changes of hue, lightness and saturation of surface colors

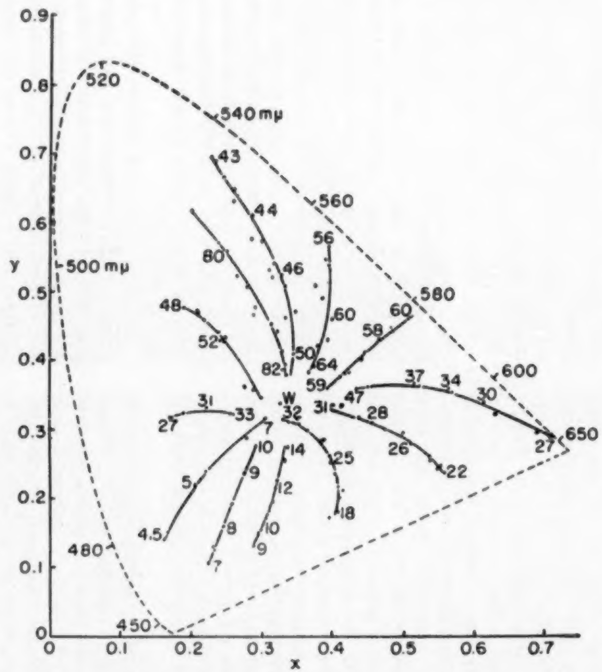


Fig. 2. Loci of constant hue in dark surround. Luminances (foot-Lamberts) necessary for constant brightness for each hue are shown by numbers printed near typical points. Different hues are not necessarily equally bright.

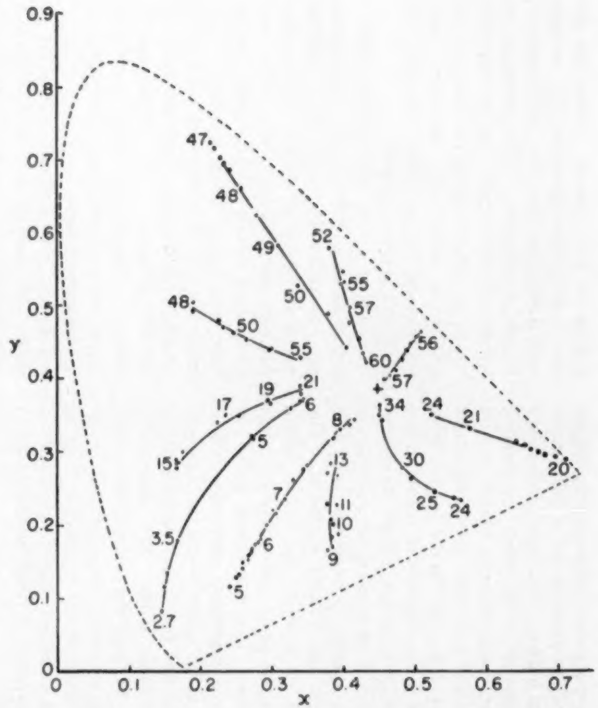


Fig. 3. Loci of constant hue for surround of approximately tungsten-light quality. Luminances for constant brightness are shown numerically.

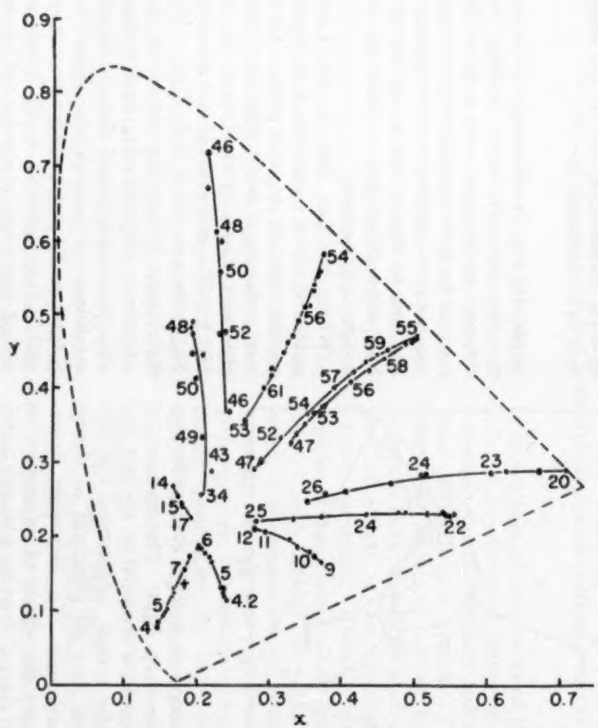


Fig. 4. Loci of constant hue for blue surround (shown by cross).

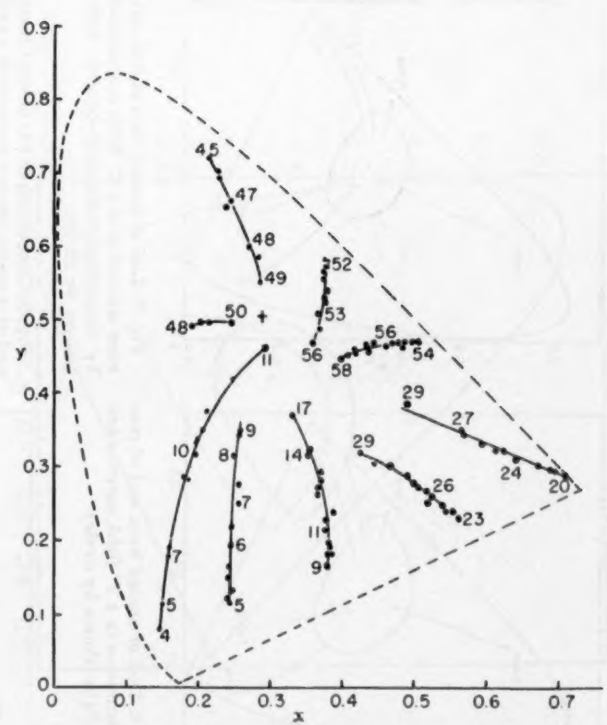


Fig. 5. Loci of constant hue for green surround (shown by cross).

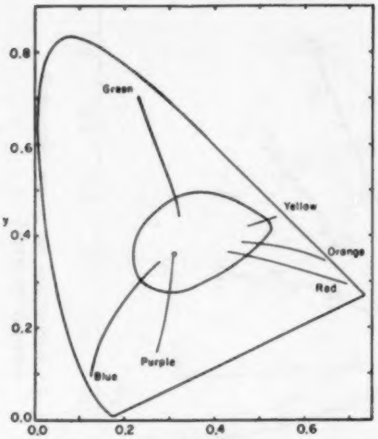


Fig. 6. Loci of named hues and of constant saturation in a 2° field, surrounded by daylight (shown by circle).

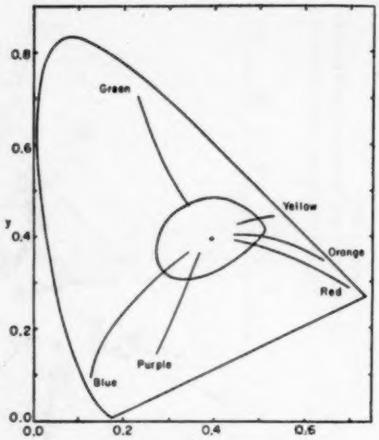


Fig. 7. Loci of named hues and of constant saturation in a 2° field, surrounded by incandescent-tungsten-quality light (shown by circle).

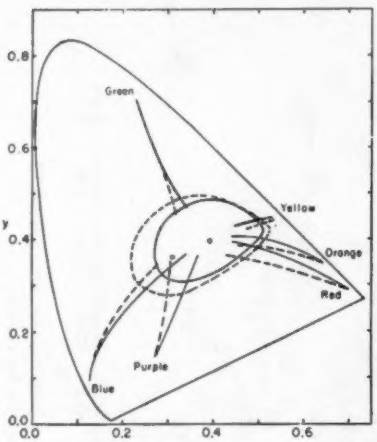


Fig. 8. Comparison of loci of same hues, and of constant but not necessarily equal saturations, in 2° field surrounded by daylight (broken-line curves) and tungsten light (solid-line curves).

in passing from daylight to incandescent-tungsten-lamp light. The meaning of their results is obscured by the fact that the color stimuli, adaptations and perceptions were all permitted to change simultaneously. To determine unambiguously the effects of adaptation on color sensation, it seems advisable either to keep the stimuli unchanged and report the hue and saturation resulting for different adaptations, or to readjust the stimulus for each adaptation so as to keep the hue and saturation unchanged, as was done by Hunt,[10] and as was done for hue, although not for saturation, in the present investigation.

Within the past year, Richter[11] has published curves purporting to represent various degrees of saturation. These were interpolated and extrapolated from the curve shown by the broken line in Fig. 9. The solid curve is that shown in Fig. 6, for adaptation to daylight. Unfortunately, Richter did not control the adaptation of his observer, nor determine what stimulus appeared white under his conditions of observation. Since his judgments of equal saturation were made with a dark surround, it might be presumed that white is represented by the

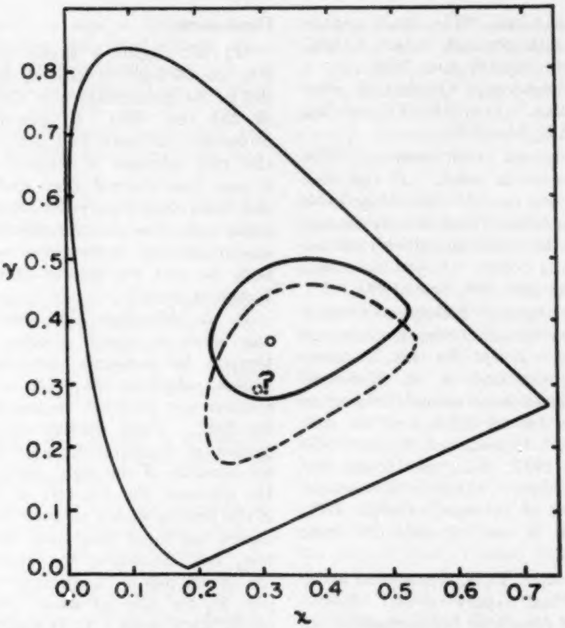


Fig. 9. Comparison of Richter's locus of constant saturation in dark surround with locus of constant saturation in daylight surround (solid-line curve).

point marked with a question mark. This guess is based on determinations of white in dark surrounds by Priest,[12] Helson and Michels,[13] Hurvich and Jameson,[14] and MacAdam.[5] However, the effects of simultaneous contrast, indicated by Fig. 2, must have resulted in a different criterion of white and a different basis for saturation for each hue. The interpolation of curves for other degrees of saturation in Richter's method was based on the implicit assumptions that white paper would appear white when seen through the instrument used to determine the curve in Fig. 9, and that the effects of simultaneous contrast would not disturb the criterion for white. Since he did not use any surround to control adaptation, these assumptions do not seem to be admissible. Therefore, the curves Richter interpolated and extrapolated are of doubtful significance.

In conclusion, it can be stated that the color of the surround influences, to an important extent, the hues and saturations perceived in a picture. The results shown in Figs. 2 to 8 are intended as a guide in estimating the kind and degree of effects to be expected with various surrounds. These results also indicate that engineers can no longer be content with looking at colors. The effects of adaptation are too great to be ignored, and are too complicated for guesswork, or for reasoning based on casual impressions. In order to deal effectively with color, it is necessary to measure color.

References

1. American Standards Association, "Method of spectral photometric measurement of color," Z58.7.1, and "Method of determination of color specifications," Z58.7.2, 1951.

2. D. L. MacAdam, "The fundamentals of color measurement," *Jour. SMPE,* vol. 31, pp. 343–348, Oct. 1938.
3. D. L. MacAdam, "Quality of color reproduction," *Jour. SMPTE,* vol. 56, pp. 487–512, May 1951.
4. Committee on Colorimetry, "The psychophysics of color," *J. Opt. Soc. Am.*, vol. 34, pp. 245–266, May 1944.
5. D. L. MacAdam, "Loci of constant hue and brightness determined with various surrounding colors," *J. Opt. Soc. Am.*, vol. 40, pp. 589–595, Sept. 1950.
6. D. L. MacAdam, "Influence of visual adaptation on loci of constant hue and saturation," *J. Opt. Soc. Am.*, in press.
7. P. J. Bouma and A. A. Kruithof, "Hue-estimation of surface colours as influenced by the colours of the surroundings," *Physica*, vol. 9, pp. 957–966, Dec. 1942; *ibid.*, vol. 10, pp. 36–46, Jan.–Feb. 1943; "Chromatic adaptation of the eye," *Philips Tech. Rev.*, vol. 9, no. 9, pp. 257–266, 1947/1948.
8. S. M. Newhall, D. Nickerson and D. B. Judd, "Final report of the Optical Society of American Subcommittee on the Spacing of Munsell Colors," *J. Opt. Soc. Am.*, vol. 33, pp. 385–418, July 1943.
9. H. Helson and J. Grove, "Changes in hue, lightness, and saturation of surface colors in passing from daylight to incandescent-lamp light," *J. Opt. Soc. Am.*, vol. 37, pp. 387–395, May 1947.
10. R. W. G. Hunt, "The effects of daylight and tungsten light adaptation on color perception," *J. Opt. Soc. Am.*, vol. 40, pp. 362–371, June 1950.
11. M. Richter, "Untersuchungen zur Aufstellung eines empfindungsgemäss gleichobständigen Farbsystems," *Z. wiss. Phot.*, vol. 45, pp. 139–162, 1950.
12. I. G. Priest, "The spectral distribution of energy required to evoke the gray sensation," *Sci. Papers, Bur. Standards* vol. 17, pp. 231–265, 1921.
13. H. Helson and W. C. Michels, "Effect of chromatic adaptation on achromaticity," *J. Opt. Soc. Am.*, vol. 38, pp. 1025–1032, Dec. 1948.
14. L. M. Hurvich and D. Jameson, "A psychophysical study of white," *J. Opt. Soc. Am.*, vol. 41, pp. 521–536, Aug. 1951.

Discussion

W. W. Lozier: I would like to have you go through briefly again what you did in the manipulation of those two parts of the test field. I missed something important in there and perhaps someone else did, because it seemed to me that if you had control over both halves of the field, and you were trying to make some sort of a photometric balance, you would come to a condition where they'd both be just the same. Now what did I miss in there?

D. L. MacAdam: The observer never was asked to match a color completely. He was, for instance, asked to establish a yellow, which in his opinion was neither reddish nor greenish, in the right half of the field. Then, during the rest of that particular experiment, he did not touch the controls of the right half of the field. He adjusted the controls of the left half of the field in such a manner that he maintained the same brightness and the same hue, but decreased the saturation. He continued this by small steps of desaturation all the way to white. He made 20 or 30 such steps. It is easiest and customary to progress from the saturated hue to white in regular sequence. Each time, he desaturated the yellow a little more and kept the brightness constant, but the thing to which we asked the observer to pay most attention was to keep the same hue, neither too orange nor too green. Therefore, each time we recorded a set of data the field was not matched completely, but was matched according to only two of the three attributes of color. It was matched in hue and matched in brightness, but not in saturation.

We did similarly for the saturation loci. In that case we asked the observer to change the hue. There was another difference from the constant hue experiment. In that, we kept the right-hand side of the field at its maximum possible saturation throughout the whole series. But in the equal saturation experiment, the observer changed the hues of both halves of the field in turn. First, he adjusted to obtain a moderate saturation of yellow in the right-hand side of the field, then the observer adjusted the controls of the left side to obtain an orange equal to the yellow in saturation and brightness.

But, of course, it was a different hue. Then he left that side of the field alone and returned to the right-hand side of the field which he adjusted to an even redder orange, equal to the other half of the field in two attributes, saturation and brightness. But the third attribute, hue, was different.

Dr. Lozier: Thank you, that helps a lot.

M. W. Baldwin, Jr.: I have two questions. First, were your observers experienced or naive?

Dr. MacAdam: They were experienced in the use of this apparatus. We're very naive in subjective judgement. If we say that two colors appear to be equally saturated, no training has contributed to that judgement.

Mr. Baldwin: My second question is, how did you convey to them what you meant by the word hue?

Dr. MacAdam: We did not attempt to teach the observer what hue means. The purpose of the experiment is to determine what the *observer* means by hue. As a matter of fact, we did not use the word hue when telling the observer what to do. We asked him to choose a yellow, for instance, that he felt sure he could remember, one in which neither red nor green was noticeable.

Mr. Baldwin: Would you have been successful with this if you had called in a mail girl as an observer?

Dr. MacAdam: If we had called in a mail boy, he might not have been sufficiently interested in color. I think a mail girl would have served very well.

Anon: Are there data now available in respect to the direct viewing of transparencies? Could your data be applied to the direct viewing of color transparencies?

Dr. MacAdam: My impression is that it could be applied in a general way, that is, one could estimate rather closely the extent of the effect, of which we have been aware for a long time, that a colored surround influences the apparent balance of a picture. I think we could now say how much the balance is influenced and how much one would have to adjust the balance in order to compensate for the effect of the surround. As for the mutual color adaptation effects of details within the picture itself, I don't believe we have enough data.

Anon: Thank you. The reason for the question is that there is now a Subcommittee of ASA charged with the responsibility of developing, possibly, an American Standard for the direct viewing of transparencies.

Visual Performance on Perceptual Tasks at Low Photopic Brightnesses*

By S. D. S. SPRAGG

Subjects, rigorously screened for visual abilities, were tested on a variety of visual perceptual tasks. A brightness range of 0.005 to 6.0 ft-L (at the subject's eye) was used. For each task a critical brightness level (approximately 0.02 to 0.05 ft-L) was found, below which visual performance was impaired (as measured by speed and accuracy scores), and above which increases in brightness produced little or no improvement in visual performance. Implications are discussed.

THE EXPERIMENTS described are part of a research project concerned with human visual performance as it is related to problems of airplane cockpit and instrument illumination. More specifically, study has been made of the minimum brightness levels needed for the effective performance of visual perceptual tasks. Toward this end, experiments have been carried out on the speed and accuracy with which subjects can read photographic reproductions of instrument dials as a function of the intensity of illumination provided. Studies have also been made on the adequacy of visual performance on such perceptual tasks as: judgments of magnitude of a common illusion, thresholds for perception of motion, accuracy of binocular depth perception, and performance on visually presented arithmetic tasks, all as a function of the amount of illumination provided.

Young adult male subjects, rigorously screened so that they constituted groups with excellent visual abilities, served as subjects. They were tested on dial-reading tasks and other visual perceptual tasks. A brightness range of 0.005 to 6.0 ft-L was used. For each task there was found a critical brightness level at approximately 0.01 to 0.1 ft-L, depending on the task. At brightnesses below this level visual performance was increasingly impaired; above this level in-

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by S. D. S. Spragg, University of Rochester, Rochester 3, N.Y.

*The research reported here has been carried out on a research contract between the University of Rochester and the Air Materiel Command, U.S. Air Forces. The experiments described have been reported in the following memorandum reports and technical reports issued by the Air Materiel Command: MCREXD-694-21 (October 1948); MCREXD-694-21A (Dec. 1948); TR 6013 (Nov. 1950); and TR 6040 (Nov. 1950). Research articles describing these studies will also be forthcoming in the *Journal of Psychology*.

creases in brightness produced little or no improvement in visual performance.

These findings suggest that for the night-time operation of equipment, and also for the viewing of complex visual stimuli at low illumination levels, brightness values should not be allowed to fall below 0.05 to 0.1 ft-L; on the contrary, they should be kept safely above this critical level in order to insure adequate visual perception.

Introduction

Instrument dials must often be read rapidly and accurately under conditions in which it is desirable to provide no more than the minimum amount of illumination necessary for the efficient performance of the task. Such conditions are found, for example, in the airplane cockpit during night flying. It has seemed desirable in the night operation of military aircraft and, perhaps to a somewhat lesser extent, for commercial aircraft, to attain and preserve as much dark adaptation on the part of the pilot and copilot as is feasible.

This demand has posed the persistent problem of the amount and nature of illumination which will best meet the requirements of the situation. Taken separately, the ideals are incompatible. On the one hand it would be desirable to flood the cockpit with a high level of white (incandescent) light. Studies of visual acuity, speed and ease of reading and performing other visual tasks, subjects' stated preferences, etc., have frequently concluded with recommendations for ambient illumination from 15–20 ft-c to 100 ft-c or even more.

On the other hand, it would be desirable to have no light or practically no light in the cockpit, so that pilot and copilot can achieve and maintain maximum dark adaptation and thus be better equipped to see and recognize other aircraft, mountains and other aspects of the terrain, etc.

A practical solution to the problem will obviously be a compromise between these two conditions. It will involve a determination of the effectiveness of visual performance under a range of intensities and spectral distributions of illumination which will: (a) permit satisfactory performance of visual perceptual tasks inside the cockpit (reading dials, etc.); and (b) maintain a level of dark adaptation sufficient for the pilot and copilot to deal adequately with visual stimuli coming from outside the cockpit.

As a beginning in a series of studies designed to contribute toward the solution of the problem, our project has undertaken certain experiments attempting to relate visual performance (as indicated by the speed and accuracy of reading dials) to the illumination provided.

Although speed and accuracy of dial reading constitute primarily a complex *perceptual* task rather than a simple *acuity* function, available information on the relationship between acuity and illumination is relevant in that it may suggest the general nature of the function as well as set a lower limit to performance.

The early study of König, as well as other more recent studies, indicated that acuity varies as the logarithm of illumination intensity, with the implication that even at high illuminations an increase in illumination will produce some increment of acuity.

Other workers, however, have reported that visual acuity increases with illumination increase only up to a relatively modest level (such as 10 or 20 ft-c) and that the increase in acuity is hardly noticeable beyond this range.

A great many recent studies, both military and civilian, have concerned themselves with factors determining acuity and other characteristics of visual performance, as a function of illumination level, in a variety of task situations. This literature has been surveyed, with differing emphases, by Fulton and his co-workers,[1] by Lawrence and Macmillan,[2] by Smith and Kappauf,[4] and others.

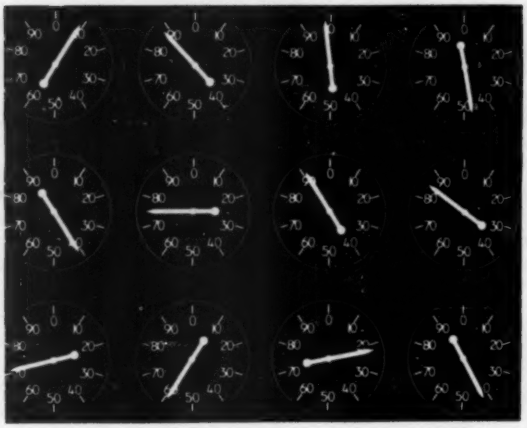


Fig. 1. A sample bank of dials, 2.8-in. diam, 100 × 10 scale.

There is still need, however, for a relating of specific visual perceptual performances, such as dial reading, to a systematically varied range of illumination values. That is the aim of the present study.

Procedures and Results

Subjects were cone dark-adapted to the illumination level being used and were then required to read banks of photographically reproduced instrument dials as rapidly and as accurately as possible. Figure 1 shows a typical bank of 12 dials. It will be noted that the scale is in ten-unit steps; thus, subjects have to interpolate to read to the nearest unit. Dials were 2.8 in. in diameter.

Two incandescent lights at about 2400 K were used as sources. They were mounted in cans and the illumination was controlled by means of ground-glass filters and accurately drilled apertures in interchangeable brass plates placed in the optical axis. A viewing distance of 28 in. was used.

Twenty young adult males who passed a rigorous visual screening were used as subjects. Preliminary practice on the task was followed by formal trials.

On the formal trials each subject read 10 cards of dials at each of five brightness levels. Time was recorded by the experimenter's starting the timer after the subject read the first dial and stopping it after he read the eleventh dial. The first and last dial readings in each card were eliminated from both the time and error data because of their relative unreliability. Thus, the data for each subject consist of 100 dials read at each of five brightness levels.

The levels of illumination were chosen as a result of exploratory experimentation which indicated that a rather sharp change in the difficulty of the dial-reading task occurs at a brightness of about 0.02 ft-L. For this experiment, therefore, two values were chosen which would closely bracket the suggested transition level, another value at slightly above cone threshold for the cone dark-adapted eye, one at 6.0 ft-L, and one at an intermediate level. The values selected were: 0.005, 0.018, 0.022, 0.296, and 6.0 ft-L.

Brightness measurements were made with a Macbeth Illuminometer used in the subject's position, and directed against an 11 × 14 in. sheet of unexposed but fixed photographic paper from the same stock as that of the dial reproductions.

A counterbalanced sequence of bright-

Table I. Dial-Reading Performance as a Function of Task Brightness (2.8-in. Dials; N = 20 Subjects)

Brightness, ft-L	No. (and %) of readings in error in reading 100 dials	Standard deviation	Mean reading time per dial, in seconds	Standard deviation
0.005	67.3	10	2.84	.93
0.018	59.9	14.1	2.64	.74
0.022	30.1	8.1	1.52	.21
0.296	27.8	5.5	1.33	.21
6.0	27.8	4.4	1.30	.22

ness levels was employed. Subjects completed the experiment in two sessions, several days apart. They were given no knowledge of results; that is, they were not told the correct readings, nor whether their readings were correct or wrong.

Table I summarizes the mean error frequencies and the mean total times. Each point is based upon 100 dials read by each of 20 subjects, therefore, upon 2000 readings.

Variances for subjects and for brightness levels were significant at the 1% level. An analysis by the "t test"* showed that, both for error frequency and for time, all differences that crossed 0.02 ft-L were significant at the 1% level, while no difference that does not cross this brightness value is significant at the 1% level. In fact, only one of them (error frequencies at 0.005 and 0.018 ft-L) is significant at the 5% level.

The error-frequency data are summarized graphically in Fig. 2 (results for 2.8-in. dials), and the data for average reading time, in Fig. 3 (also 2.8-in. dials). Inspection of these two figures shows that the error curve and the time curve are highly similar. By both measures, there is strong evidence that in this rather complex visual perceptual task there is marked improvement at about 0.02 ft-L and relatively little improvement thereafter, at least up to 6.0 ft-L. We have made informal observations indicating no significant improvement at levels considerably higher than this.

Because of the fact that these findings are based on fairly large dials with widely-spaced scale divisions, it was decided to repeat the experiment with smaller dials and finer scale-division spacings. Accordingly, a second experiment was run, using dials which were 1.4 in. in diameter and had scale marks for every unit instead of every ten units, as in the above experiment.

The general procedures were the same as in the preceding experiment. Ten subjects were used and (because of the setup demanded by another concurrent study) brightness levels of 0.005, 0.01, 0.05, 0.1, and 1.0 ft-L were employed.

The results of this experiment are summarized in Table II which shows the proportional error frequency and the mean time required, for the several brightness levels. It will be seen that there is a sharp improvement in performance up to 0.1 ft-L and relatively slight improvement above that level.

The results for the 1.4-in. dials are shown graphically in Figs. 2 and 3, in which are plotted the error data and the time data. Again it will be seen that

* The t test is a statistic frequently used to evaluate the probable genuineness of an obtained difference between two sets of means. For example, a difference which the t test shows to be "significant at the 1% level" is a difference which would have occurred by chance fluctuation only 1 time in 100, and therefore can be regarded with a high degree of confidence as a genuine difference (cf. the sections on small sample statistics in a standard statistics textbook).

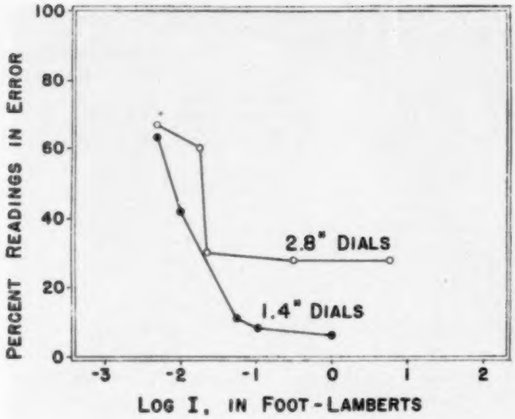


Fig. 2. Frequency of errors in reading large dials (2.8-in. diam, 100 × 10 scale) and small dials (1.4-in. diam., 100 × 1 scale) as a function of brightness.

Table II. Dial-Reading Performance as a Function of Task Brightness (1.4-in. Dials; N — 10 Subjects)

Brightness, ft-L	No. of readings in error in reading 50 dials	Standard deviation	% of readings in error in reading 50 dials	Mean reading time per dial, in seconds	Standard deviation
0.005	31.3	8.0	62.6	3.45	1.33
0.01	20.8	7.8	41.6	2.79	0.66
0.05	5.7	4.0	11.4	1.77	0.21
0.1	3.9	2.8	7.8	1.71	0.24
1.0	3.2	2.1	6.4	1.55	0.21

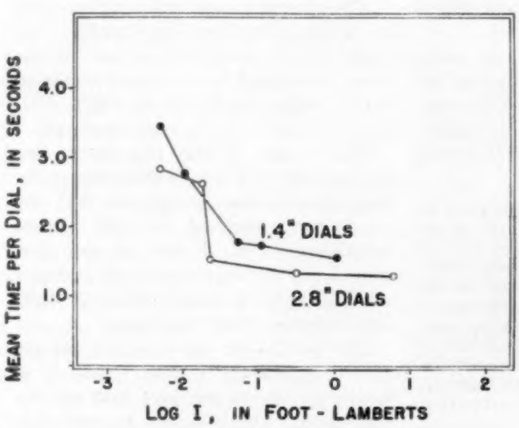


Fig. 3. Mean time in seconds required to read large dials (2.8-in. diam, 100 × 10 scale) and small dials (1.4-in. diam, 100 × 1 scale) as a function of brightness.

performance improves markedly with increased brightness up to the 0.01–0.1 brightness level, but there is little improvement in performance above this level.

Inspection of Figs. 2 and 3 permits a comparison of results for the larger, coarse-scaled dials and the smaller, fine-scaled dials. It will be seen that: (a) at the lowest brightness level, performance is about the same, approximately two-thirds of the readings being in error in each case; (b) between 0.01 and 0.1 ft-L there is rapid improvement in both cases, and relatively little improvement above this level; and (c) that performance levels off at a poorer performance value for the large dials, with their widely-spaced scale divisions and the necessity for making interpolations, than it does for the smaller, more finely-spaced dials where no interpolations are necessary.

The same comparison can be made for time scores. Very little difference in results is to be noted here. If anything, performance is somewhat slower with the smaller, finely-spaced dials.

These results seem to indicate that there is a critical brightness level below which subjects find it difficult to perform this dial-reading task, as shown by relatively slow responses and greater frequency of errors. Above this level, the task becomes suddenly much easier, responses are quicker, and frequency and magnitude of errors much less. Further increases in brightness, however—at least up to 6.0 ft-L and very probably indefinitely—produce no further increments of performance. It seems as though once a subject has been given just enough brightness to perform this task with ease, brightness is no longer a significant variable.

This finding is in interesting contrast with König's classical curve relating acuity to brightness, and to the findings of certain recent investigators that acuity continues to increase even at very high brightness levels. Other workers, whose data indicate that acuity ceases to increase beyond a certain brightness level, have usually reported that their curves do not flatten out until about 5 to 10 ft-c of illumination.

No real discrepancy exists between such findings and the present results. Our data were taken in a complex perceptual task in which adequacy of performance is a function not only of acuity and contrast, but also of speed and accuracy in making the complex judgment which an interpolation represents. Since we are dealing with a task which is far more complex than a simple resolving power function, the lack of close correspondence between our results and the earlier acuity studies should not be disturbing.

I wish to mention some further studies in this general area which were carried out by Dr. Milton L. Rock of our project.[3] The problem undertaken was a systematic examination of the adequacy of performance of four rather widely-varied visual perceptual tasks over a range of low photopic brightnesses. The tasks chosen were: (1) magnitude of judgment error in a conventional Müller-Lyer illusion figure; (2) absolute threshold for perception of movement of an alternately black and white striped field; (3) accuracy of binocular depth perception in a modified Howard-Dolman type apparatus; and (4) performance in a series of visually presented addition tasks (a 3-digit number followed by a 2-digit sum, and the subject is required to state whether it is or is not the correct sum of the first three digits). These four tasks were chosen to represent a rather wide range of visual perceptual tasks as far as complexity is concerned.

Subjects, screened visually as in our previous experiments, were tested on these tasks at the following brightness levels: 0.005 (which is just above cone threshold for the cone dark-adapted eye), 0.01, 0.05, 0.10, and 1.0 ft-L. The viewing distance was 28 in. for each task.

I am not going to describe the details of these four experiments, but shall

attempt to indicate briefly the principal results.

For the Müller-Lyer figure, mean errors in judgment decreased sharply as brightness increased from 0.005 up to 0.05 ft-L, but there was practically no improvement for brightnesses higher than this value.

For the experiment on absolute motion threshold performance improved sharply as brightness was increased from the lowest values up to 0.1 ft-L, then only slightly from there up to 1.0 ft-L.

For the depth perception experiment, increased brightness brought a marked increase in accuracy of judgments from the lowest brightness up to 0.05 ft-L and little or no increase above this level.

Finally, in the addition task, improvement in performance was marked from the lowest level up to 0.05 ft-L, then stayed at essentially the same value for the two highest brightness levels.

For all four of these visual tasks, when performance is plotted against brightness level we find *rapid* improvement in performance as brightness is increased—up to a certain level and beyond this level, increases in brightness bring relatively slight increments of performance. This critical level seems to be between 0.01 and 0.05 ft-L for the Müller-Lyer, the depth perception, and the addition tasks, and between 0.05 and 0.1 ft-L for the motion threshold task. It will be recalled that in the dial-reading experiments this critical value was estimated to be about 0.02 ft-L in one experiment and between 0.01 and 0.05 ft-L in the other.

Conclusions

Evidence seems to be accumulating that for visual tasks of a perceptual nature (in contrast to simple acuity functions) there is a critical brightness level (probably between 0.01 and 0.1 ft-L, depending on the task) below which subjects find it difficult to perform the task, and performance is relatively poor, while above this value the task becomes much easier, responses are faster and more accurate, and additional increments of brightness make relatively little difference.

From a practical standpoint, the findings from these studies indicate that in visual perceptual situations where maximum performance is required with a minimum of brightness (in order, for example, to conserve dark adaptation), great care should be taken that the brightness level not be allowed to drop below about 0.05 to 0.1 ft-L.

These findings have implications for the night operation of equipment, e.g., aircraft, and also for the viewing of complex visual stimuli at low levels of illumination. If the visual material to be perceived has a brightness safely above 0.05 ft-L, then the visual perception of that material will be as rapid and as accurate as it would be if the brightness were at higher levels (at least up to 6 ft-L, and possibly indefinitely). Our results do not, however, provide data bearing on the problems of: (1) fatigue effects of long-continued viewing under these conditions; or (2) individual preferences. Further research is needed to supply information here.

References

1. J. F. Fulton, P. M. Hoff and H. T. Perkins, *A Bibliography of Visual Literature, 1939–1944*, Geo. Banta, Minasha, Wis., 1945.
2. M. Lawrence and J. W. Macmillan, *Annotated Bibliography on Human Factors in Engineering Design*, Aviation Br., Research Div., BuMed, U. S. Navy, 1946.
3. M. L. Rock, "Visual performance as a function of low photopic brightness levels," USAF, Air Materiel Command, TR 6013, Nov. 1950.
4. W. M. Smith and W. E. Kappauf, "Studies pertaining to the design and use of visual displays for aircraft instruments, computors, maps, charts, and tables," USAF, Air Materiel Command, TSEAA-694-1G, May 1947.
5. S. D. S. Spragg and M. L. Rock, "Dial reading performance as related to illumination variables. I. Intensity,"

USAF, Air Materiel Command, MCR-EXD-694-21, Oct. 1948.
6. S. D. S. Spragg and M. L. Rock, "Dial reading performance as related to illumination variables. III. Results with small dials," USAF, Air Materiel Command, TR 6040, Nov. 1950.

Discussion

Ben Schlanger: Was consideration given to the time factor, that is, do you know the effect after one or two hours of viewing?

S. D. S. Spragg: Our experimental session typically lasted forty to forty-five minutes and there was no significant change in performance toward the end of this period. Our data, however, do not contribute anything to what might be called fatigue studies. Our results have no implications for continuous viewing that may extend for several hours under these conditions, although there are relevant studies which show that visual fatigue in tasks of this sort is almost impossible to demonstrate. Dr. Brian O'Brien has shown that, and Carmichael and Dearborn have also shown it for periods up to, maybe, seven or eight hours.

O. W. Richards: Your work was done at relatively close distances. I was wondering if you have any information that would apply to farther distances where convergence and other factors wouldn't enter. In other words, do you view this as entirely a general factor or do you think it involves other problems?

Dr. Spragg: These experiments were all carried out at 28-in. distance which is the standard distance recommended for research on visual performance, or problems, in the cockpit, as specified by the Visual Standards Committee of the NRC Vision Committee, and it is an extrapolation to generalize from our data to distant conditions. The details of our visual task were never much less than five minutes of angle and were all viewed at 28-in. distance.

Anon: Dr. Spragg, can you tell me, regarding visual acuity and low brightness, what effects of color, primarily red, were shown in the study?

Dr. Spragg: We have carried out two studies on dial reading under different qualities of illumination, using Corning sharp cut-off filters. I didn't report them here because I wanted to restrict this report primarily to the brightness problem. I might say, very briefly, that, as you suspect, we're interested in the red and yellow region because that region of the spectrum is important for maintenance of dark adaptation. We found that if we took a good deal of care to make the color values equal, as determined by heterochromatic color matching, so that we could say that we had red at 0.1 ft-L, red at 0.01 ft-L, and also yellow and other colors at the same value, that color made no difference if we stayed above this critical level of about 0.02 ft-L; that is, performance was neither worse nor better with red, orange or yellow than it was with green. However, if we got below 0.02 ft-L, color still didn't seem to make very much difference, but red was worse than the other colors viewed. Thus, if red illumination is used for night operations and for reading instruments, it would seem more than ever crucial to keep the red illumination above this 0.02 ft-L level.

Surround Brightness: Key Factor in Viewing Projected Pictures

By SYLVESTER K. GUTH

The lighting of areas where projected pictures are viewed presents a number of specialized problems to the lighting engineer. However, these specialized problems involve factors of lighting design rather than any particularly unusual visual factors. Basically, projected pictures are visual tasks upon which the eyes and attention of the viewers are concentrated for extended periods. Since the viewing of projected pictures is a seeing task, two distinct objectives are suggested: (1) providing maximal visibility of the task; and (2) providing maximal visual comfort and ease of seeing. These are fundamental objectives that murt be satisfied in order to obtain optimal seeing conditions in any visual situation. This paper is confined chiefly to the second objective and to those factors which determine whether the area in which projected pictures are viewed is visually satisfactory. The screen is introduced only insofar as it influences or is influenced by the environmental factors.

The brightness characteristics of various portions of the visual field surrounding the central or task area are of overwhelming importance in providing a comfortable visual environment.[1] These brightnesses, and their relationships to the brightnesses of the task, contribute favorably or unfavorably to the seeing conditions. They may influence directly the visibility of the visual task, or their effects may be more subtle and result in decreased ease of seeing. Obviously, both effects may be and often are produced simultaneously, especially when prolonged seeing is involved.

The difficulty of obtaining adequate auditorium brightnesses in theaters has often resulted in minimizing the importance of the surround brightnesses for ability to see and comfort of viewing. The lack of reports of discomfort has been used as one of the principal arguments for considering that there is nothing wrong with the existing viewing conditions. Such lack of complaints should merely be taken as the audience acceptance of what it is used to, just as it has done in many other fields. Since the motion picture is a visual task, the consideration of light and lighting can and should include the same factors that apply to other visual situations.

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by Sylvester K. Guth, General Electric Co., Nela Park, Cleveland 12, Ohio.

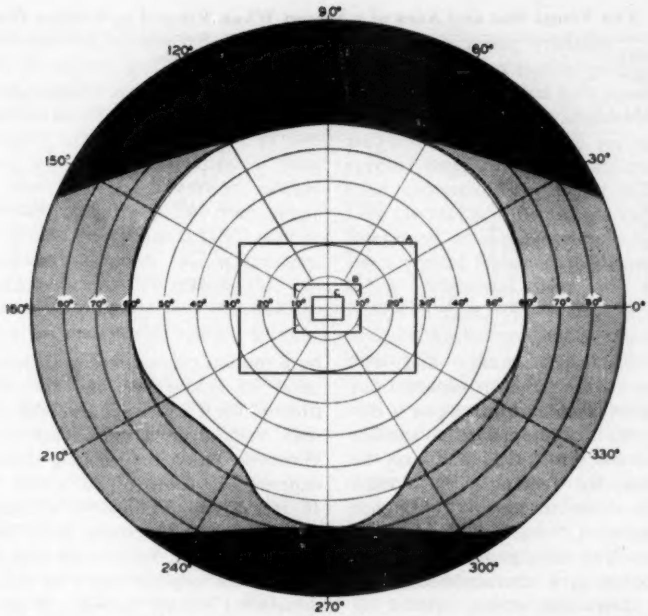


Fig. 1. A diagrammatic representation of the monocular and binocular visual fields. The portions occupied by a motion picture screen when viewed at three distances, corresponding to the screen width W, $3W$ and $5W$, are illustrated by rectangles A, B and C, respectively. Shaded areas (right and left) represent portions of the visual field seen only by the right and left eyes, respectively. Unshaded area represents that portion of the visual field seen by both eyes.

Basic Considerations

In order to understand the importance of the surrounding conditions in the central field, it may be well to consider briefly the relative magnitudes of the two areas. The angular extent of the entire binocular visual field varies with the individual physiognomy and averages about 200° horizontally and 130° vertically, and is approximately elliptical in shape. The limits of various portions of the visual field are illustrated in Fig. 1. The unshaded area indicates the portion of the visual field in which objects can be seen by both eyes. The two shaded areas on the right and left represent those portions of the visual field that can be seen only by the right and left eyes, respectively.

The Task Area. A visual task usually occupies a limited region in the central portion of the visual field and its apparent or visual size is a function of the distance from which it is viewed. A motion picture screen, for example, appears large or small depending upon whether it is viewed from the front or rear of a theater. The three rectangles superimposed upon the visual field, illustrated in Fig. 1, represent a motion picture screen viewed from three different positions in an auditorium. In order to be applied generally to any size screen, the viewing distance is expressed in terms of the screen width, W. Thus, a screen viewed at a distance corresponding to the screen width, W, is represented by rectangle A, the angular extent of which

Table I. The Visual Size and Area of a Screen When Viewed at Various Distances

Viewing distance in screen widths	Angular subtense of screen degrees Width	Height	Solid angle subtended by screen steradians	Per cent of visual field
W	53.1	41.1	0.75	15.0
$2W$	28.1	21.2	0.19	3.8
$3W$	18.9	14.3	0.083	1.7
$4W$	14.3	10.7	0.047	0.94
$5W$	11.4	8.6	0.030	0.60
$6W$	9.5	7.2	0.021	0.42
$7W$	8.2	6.1	0.015	0.30
$8W$	7.2	5.4	0.012	0.24

is about 53° horizontally and 41° vertically. If the screen is viewed from the rear part of an auditorium, or a distance of $5W$, it occupies a much smaller portion of the visual field and may be represented by rectangle C. When viewed at this distance, it extends approximately 11° horizontally and 8° vertically. The intermediate rectangle B corresponds to a viewing distance of about 3 times the screen width. It should be noted that in some theaters a screen may appear even smaller than the one indicated by C.

It is seen that even when the screen is viewed from a short distance, it occupies a relatively small portion of the binocular visual field. The importance of the peripheral regions can be emphasized by considering the relative areas involved. A convenient and expressive unit of apparent area is in terms of the solid angle, Q, in steradians,* subtended by a surface which combines the actual projected area with the distance from the eye to the center of the surface. Thus, the relative extent of a surface can be expressed as a percentage of the total solid angle subtended by the entire binocular visual field which is approximately 5 steradians. The solid angle subtended by a motion picture screen is dependent upon its actual size and the distance from which it is viewed, and both of these may vary over a considerable range. However, when the viewing distance is expressed in terms of the screen width, W, it is possible to illustrate the ranges of apparent sizes of screens as in Table I. It is seen that as the viewing distance increases, the angular extent of the screen diminishes rapidly between W and $2W$, and progressively more slowly for distances greater than $2W$. A more significant comparison is the solid angle in steradians subtended by the screen and the per cent of the visual field occupied at various viewing distances. Except for those who sit very close to the front of the theater, the screen occupies less than about 4% of the visual field, and for the average viewer less than 1%. Thus, it is obvious that the magnitude of the peripheral region of the visual field makes it extremely important to the viewer of projected pictures. Consequently, this area cannot be neglected when designing the lighting for comfortable seeing conditions.

When it is considered that the viewing of projected pictures involves a dynamic rather than a static visual situation, the area immediately surrounding the screen becomes even more important. In order to see all of the picture details, the eye may rove over the entire screen, the angular movement depending upon the viewing distance. Thus, at times, the

* The solid angle, Q, in steradians is equal to the projected area of a surface divided by the square of the distance from the surface to the eye; i.e., $Q = \frac{A}{D^2}$.

line of vision may be directed toward the edge of the screen and then the screen surround is close to the line of vision. For the longer viewing distances, a relatively small angular movement of the eyes will bring the screen surround into nearly direct view. Therefore, unless the surround brightness has been properly adjusted, the viewer is faced with a considerable variation in adaptation brightness which can do nothing but detract from his pleasure and comfort by providing an undesirable visual environment.

When designing lighting, it is necessary to consider the various characteristics and requirements of the visual task. While the viewing of projected pictures usually involves prolonged periods, the task involves some factors that are different from those pertaining to other tasks such as reading. Much of the information or the story is obtained by words and the gestures, facial expressions and actions of the performers. Therefore, visual acuity is less important than the discrimination of a wide range of brightness contrasts. The viewer is not confronted with the problem of resolving small details near the threshold in size. However, while discrimination of the characteristics of the visual task may not be critical, the eyes and attention are focused steadily with but brief respites.

Adaptation Brightnesses. In any specific situation, the desirable surround brightness is dependent upon the brightness level to which the eyes are adapted. Therefore, it is necessary to determine the relationship between the picture brightness and the surround brightness. However, the former varies over a considerable range, depending upon projection-equipment, theater and screen sizes, film characteristics, etc. It may range from a very low level for the opaque projectors used in educational work to the high levels obtained with slide projectors. Nevertheless, it is possible to develop a concept in terms relative to the screen brightness obtained with the projector running without film. Furthermore, since a motion picture, or any sequence of projected still pictures, presents a continuously variable brightness pattern, it is difficult to arrive at any specific brightness that can be considered representative of all conditions. One method is to record the variation in integrated or average-picture brightness for a typical film and to determine the mean brightness over an extended period of time. However, the range of average brightnesses, especially the minimum values, are of importance.

A typical record for a black-and-white film is shown in Fig. 2. The film used included photographs of almost completely white areas to extremely dark night scenes and can be considered to be representative. In order to make the record of Fig. 2 more universal in its application, the ordinate is shown as per cent of clear-screen brightness. Thus, it is a simple matter to convert the relative values to actual brightnesses. For example, in terms of the clear-screen brightness, the maximum average brightness recorded for the lightest scene was about 25%; the minimum brightness was 1.0%; and the mean value for the entire film was about 10%. Therefore, when the clear-screen brightness is 15 ft-L, the picture brightnesses are approximately 3.8 maximum and 0.15 minimum with a mean of 1.5 ft-L. It is interesting to note that these values compare favorably with those obtained by Logan.[2]

A similar record taken with an industrial color film gave a mean brightness of about 5% of the clear-screen brightness with maximum and minimum values of 16% and 1%, respectively. For a clear-screen brightness of 15 ft-L, these brightnesses are a mean value of 0.75, a maximum of 2.4, and a minimum of 0.15 ft-L. Obviously, there will be quite a wide variation among films. However, these brightnesses appear to be within the range of what is obtained in representative theaters.

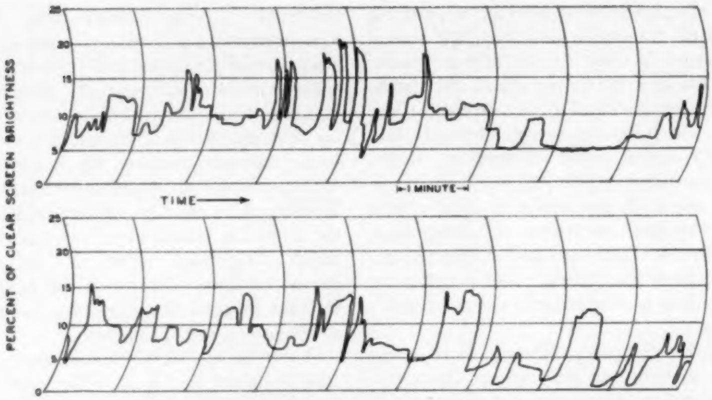


Fig. 2. A record illustrating the variation in integrated or average brightness of a typical motion picture in terms of the clear-screen brightness.

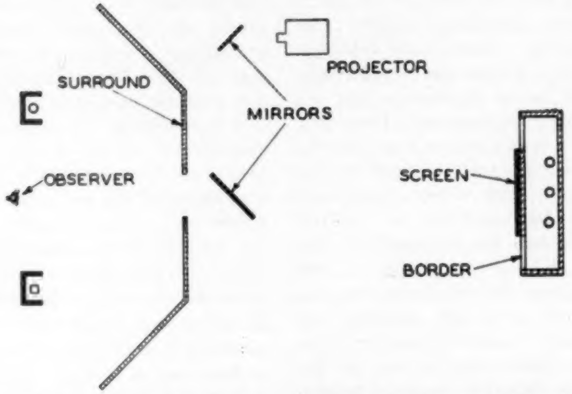


Fig. 3. The experimental arrangement used for determining the desired border and surround brightness when viewing projected pictures.

Experimental Arrangement

In order to isolate and to control independently the brightnesses of the various areas in the visual field, the experimental arrangement illustrated in Fig. 3 was adopted. This is a modified scale model of a theater in which 1 in. equals 1 ft. The screen was 20 in. wide, thus corresponding to a 20-ft screen. The observers were located at a distance of six times the screen width from the plane of the screen, or a distance of 120 in. Immediately surrounding the screen was a transilluminated diffusing glass, the brightness of which could be adjusted by the observers. This area corresponds generally to the area on a stage surrounding a motion picture screen and is termed the screen border. Between the observer and the screen was a panel, the brightness of which could be independently controlled. The observer viewed the projector screen through a rectangular aperture in the panel. This

aperture was of such a size that the trans-illuminated screen surround could be seen by the observer. This arrangement enabled control of the two surround brightnesses without permitting any stray light to reach the screen. While this experimental arrangement does not duplicate exactly the visual situation of a theater, it is considered to be sufficiently typical for the present purposes.

In the present investigation, which was intended only to be exploratory, clear-screen brightnesses ranging from 1.1 to 60 ft-L were used. These include brightnesses that are obtainable with various types of projection equipment such as highly efficient projectors used at a relatively short projection distance, opaque projectors, slide-film projectors, etc. The brightnesses were obtained with a standard 16-mm projector in which were used lamps of 200, 300 and 750 w for screen brightnesses of 11, 25 and 60 ft-L, respectively. By means of a neutral-density filter, these brightnesses could be reduced to one-tenth of these values for a lower range of 1.1, 2.5 and 6 ft-L. These clear-screen brightnesses corresponded to mean picture brightnesses ranging from 0.1 to 6 ft-L.

The observers viewed the motion picture and, for each value of clear-screen brightness, adjusted the brightness of the border until they deemed it most desirable for viewing the projected picture. Their judgment was based upon viewing comfort and upon the appearance of the projected pictures. A group of five observers made a series of five observations on each of two sittings for the various screen brightnesses. Each observer was permitted as long a period to make each observation as he felt necessary. Each series of observations included representative portions of the motion picture.

Experimental Results

Influence of Screen Brightness. The average brightnesses of the border selected by the observers are plotted in Fig. 4 for clear-screen brightness ranging from 1.1 to 60 ft-L. The observed data for viewing motion pictures are represented by the open circles. These points can be represented by a straight line, indicating a linear relationship between the logarithms of the clear-screen brightness and the selected border brightness. Since the average-picture brightness is approximately one-tenth of the clear-screen brightness, the scale at the top of Fig. 4 illustrates the average-projected-picture brightnesses for corresponding clear-screen brightnesses. The picture brightness is a more representative value, since it can be considered as the brightness to which the eyes are adapted.

A similar investigation was conducted with a typical black-and-white slide film. The solid dots indicate the average border brightnesses selected by two of the observers for four screen brightnesses, ranging from 1 to 20 ft-L. These values check very well with those obtained with motion pictures. In other words, the fact that the observer is viewing a still or motion picture does not seem to influence his decision regarding the most suitable border brightness. Similar results were obtained with a color film.

It was found that the surrounding screen brightness had no significant effect upon the selection of the border brightness, provided that it was equal to or less than the latter. None of the observers desired a zero surround brightness. The general preference was about one-half the border brightness. All who viewed the projected pictures in the experimental situation were unanimous in indicating that the border brightness was of greatest importance. Therefore, the following discussion is based primarily upon the border brightnesses selected by the observers for the various screen brightnesses.

The desirable border brightness is not a simple function of the clear-screen or average-picture brightness, but is exponential, and may be represented by:

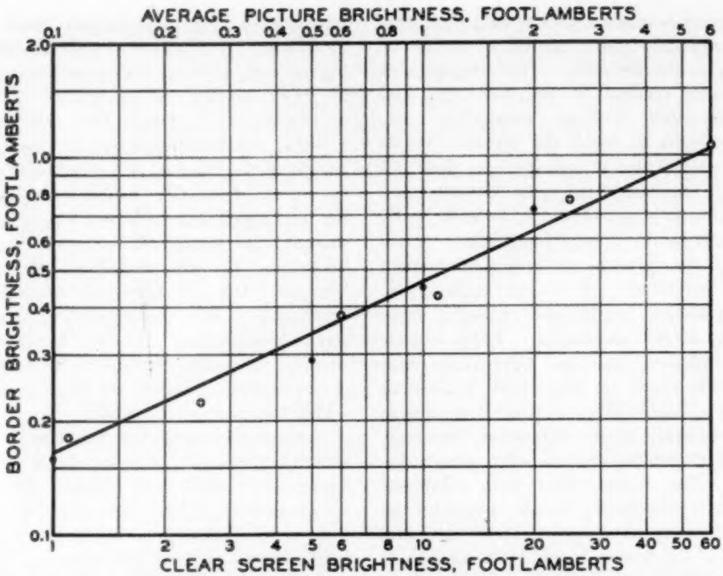


Fig. 4. The relationship between desired border brightness for various clear-screen and average-picture brightnesses. The open circles and solid dots represent observed values obtained with a motion picture and slide film, respectively.

$$B = 0.16\ S^{0.46} \qquad (1)$$

$$\text{or} \quad B = 0.46\ P^{0.46} \qquad (2)$$

where B, S and P are the border, clear-screen and mean-picture brightnesses, respectively. A simple approximation is that the border brightness is equal to the square root of the screen (or picture) brightness multiplied by a constant. In terms of average-picture brightness, the desired border brightness is indicated to be about one-half of the square root of the picture brightness.

It may be of interest to compare the above equations with one developed from data obtained in an earlier investigation of comfortable brightness relationships in interior lighting.[3] The relationship between the brightness, B, of a light source and the brightness, F, of the adapting field was found to be:

$$B = 302\ F^{0.44} \qquad (3)$$

In the three equations, the brightness of a light source or luminous area outside of the region of a visual task is expressed as a function of the brightness to which the eyes are adapted. The coefficient is dependent upon the criterion, the visual sensation being studied and other experimental factors. However, the similarity between the exponents is particularly significant and illustrates a common basis for the two investigations. Since most visual functions follow well-established laws and patterns, it should be expected that similar relationships would be obtained.

The ratio between the border and picture brightnesses is a variable one. For example, when the picture brightness is 0.2 ft-L (corresponding to a clear-screen brightness of 2 ft-L), the indicated border brightness is 0.22 ft-L. This is approximately equal to the average-picture brightness. However, when the picture

brightness is 2 ft-L, the desired border brightness is 0.63 ft-L or about one-third of the average-picture brightness. In other words, relatively lower border brightnesses are desired for higher picture brightnesses than for the lower picture brightnesses. This is understandable, since an important factor is the total luminous flux directed toward the eye by the area surrounding the screen. Furthermore, the eyes become progressively more sensitive to brightness differences as the adaptation brightness is increased. Therefore, relatively lower border brightnesses will be selected for the higher picture brightnesses. Nevertheless, these indicated desirable border brightnesses are considerably higher than those indicated by other investigators.[2,4]

It is emphasized that the technique used in this investigation eliminated the factor of stray light upon the screen. These relatively high border and surround brightnesses may be impractical in existing theaters. Nevertheless, these results do indicate that under ideal conditions, higher brightnesses are desirable. They should be obtainable in a properly designed auditorium.

Stray Light. In the usual auditorium, a limiting factor which governs the permissible surround brightness is the amount of stray light reflected upon the screen. Therefore, a brief investigation was made to determine the amount of stray light which would produce a just barely perceptible effect upon the picture quality. A small source of light, mounted on the rear of the surround screen, was variable and controlled by the subject. This source provided a variable amount of stray light upon the picture screen. The observer viewed the projected picture, simultaneously varying the amount of stray light until he deemed it to be a maximum without affecting the quality of the picture. This was investigated with two picture brightnesses. When the picture brightness was 0.50 ft-L (clear-screen brightness equal to 5 ft-L), it was found that a stray-light brightness of about 0.07 ft-L produced no effect upon the picture. For a picture brightness of 3 ft-L (30-ft-L clear-screen brightness) the stray light could be increased to 0.15 ft-L.

Referring to Fig. 4, it is seen that the border brightness for a picture brightness of 0.50 ft-L is 0.33. Thus, the stray-light brightness is about one-fifth of the border brightness. A similar ratio was found for the picture brightness of 3 ft-L, where the desired border brightness was 0.76 ft-L and the permissible stray light was 0.15 ft-L.

Color Film. A similar brief investigation was made with a color film. While the one used may not be exactly representative of the usual production films, it does make possible a qualitative appraisal of desired border and stray-light brightnesses. The average-picture brightness was found to be about 5% of the clear-screen brightness, which is half of the average-picture brightness of the black-and-white film. This is lower than that found by Logan,[2] whose measurements indicated a higher average-picture brightness for color film than for black-and-white film. The results obtained with two observers indicated that the border brightness desired when viewing the color film corresponded to that obtained for the black-and-white film. In other words, it appears that the border brightness is a function of the average-picture brightness and that viewing color pictures has no measurable effect upon the desired brightness.

On the other hand, it was found that stray light upon the screen was more effective for color film than for black-and-white film. For equal picture brightnesses, the maximum tolerable stray light for viewing color film was about one-half that found to be tolerable for black-and-white film. These results are logical and to be expected. The shading and blending of colors and their contrasts are important factors in the appearances of projected color pictures. On the other hand, a black-and-white

picture involves a range of neutral values which are merely shifted slightly to lighter tones by the stray light. For example, in the latter case, for an average-picture brightness of 1 ft-L, it is assumed that the white and black brightnesses are 5 and 0.05 ft-L, respectively. The tolerable stray light for this condition would be about 0.10 ft-L (one-tenth of the average picture brightness). Calculated values of contrast between the black and white areas without and with stray light are 99% and 97%, respectively. Similar calculations for other picture areas yield correspondingly small changes in contrast. In other words, the stray light selected as maximal tolerable produces too small a change in contrast to be significantly visually effective. Calculations for color pictures would be considerably more complex since they would have to involve a consideration of color change as well as a change in brightness. The former probably is the reason for a lower tolerance of stray light when viewing color pictures.

Conclusions

The relationships between average-picture brightness, border and surround brightnesses, and the stray light make it possible to predict or to predetermine the conditions that are expected to be most satisfactory in any theater. A simple rule would be to raise the border and surround brightness to the value that will not produce an excessive level of stray light upon the screen. Of course, the brightness of the border should not exceed that found desirable for the available average-picture brightness. For example, for a typical theater, if the clear-screen brightness is 10 ft-L and the average-picture brightness is 1 ft-L, the border brightness should be about 0.45 ft-L, but the stray light should not produce a brightness greater than 0.09 ft-L.

The values of border and surround brightnesses indicated by this investigation are somewhat higher than those published by others. Logan, for example, has suggested a surround brightness of 0.10 ft-L for an average-picture brightness of 1 ft-L.[2] This is about one-fifth of the value determined in the present investigation. Others have reported surround brightnesses of the order of 0.05 ft-L to be desirable.[4] A review of the limited literature on the subject indicates that most of the values have been based upon empirical attempts to apply data obtained with experimental and environmental conditions that are not directly applicable to the viewing of projected pictures. Nevertheless, there is the common conclusion that some brightness is required in motion picture theater auditoriums.

Another important aspect of brightness in viewing areas is the sources which produce the low brightnesses on the border, walls, ceiling and floors. At the low visual adaptation levels these sources and any other areas of relatively high brightness must be kept to a minimum in order for them not to be distracting or even uncomfortable. A method has been developed for determining the tolerable brightnesses of sources, such as aisle lights, bright areas of walls, fixtures, etc. In essence, they must be reduced in brightness and area so that their visibility does not compete with the visibility of the projected picture. The permissible brightnesses of such areas is a function of the size of the source or bright wall area, its position in the visual field and the average-picture brightness. This method has been described in detail elsewhere.[3,5] While it was not developed for the projected picture problem, the general principles involved should be applicable to any visual environment.

There are other factors which may have an important influence upon the final accepted or desirable surround brightnesses. These include, especially, the psychological factors which govern the mood of, and impressions gained by

the viewers. In other words, the actual brightness level used should enhance the illusions being created by the motion picture. Theoretically, at least, the viewer is asked to place himself in the actual situation being created on the screen, be it the hot sunlit desert or the dark mysterious passageways of a haunted house. Environmental brightnesses must enhance and not destroy these effects. Thus, there are many aspects to the problem of providing the surround brightnesses for viewing the projected pictures. Ultimately, all of them must be investigated before their individual importances in any situation can be evaluated. Perhaps a semi-variable control system will be necessary. Whatever is required should be determined by carefully conducted investigations rather than empiricisms or opinions.

It is emphasized that the investigations and results presented in this paper are exploratory. A primary purpose was to develop a technique that would enable observers to make considered appraisals of the environmental brightnesses in an experimental situation that approximated actual viewing conditions. Since the observers used in these studies have been used in a number of earlier investigations, and were selected as being representative, it is believed that the brightnesses selected by them are indicatory of the levels that are desirable.

References

1. Matthew Luckiesh, "Brightness engineering," *Illum. Eng.*, vol. 39, pp. 75–92, Feb. 1944.
2. H. L. Logan, "Brightness and illumination requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.
3. Matthew Luckiesh and S. K. Guth, "Brightnesses in visual field at borderline between comfort and discomfort (BCD)," *Illum. Eng.*, vol. 44, pp. 650–670, Nov. 1949.
4. L. A. Jones, "Interior illumination of the motion picture theatre," *Trans. SMPE*, pp. 83–96, May 1920.
   B. O'Brien and C. M. Tuttle, "An experimental investigation of projection screen brightness," *Jour. SMPE*, vol. 26, pp. 505–517, May 1936.
5. Sylvester K. Guth, "Comfortable brightness relationships for critical and casual seeing," *Illum. Eng.*, vol. 46, pp. 65–75, Feb. 1951.

Discussion

O. W. Richards: I was wondering if you'd care to make any comment on how the color temperature of your surround lighting should compare with the border lighting?

S. K. Guth: In this investigation we were not particularly concerned with the spectral quality of the border lighting. However, we did use filters over the lamps used for the border brightness and used special combinations of fluorescent lamps for the surround brightness so that the color would be as unobtrusive and neutral as possible. Both could be considered so-called white and differences were inconspicuous. Any significant difference between, for example, the relatively lower color temperature of filament lamps (3000 K) and the relatively higher color temperature of daylight (6000 K) would have to be investigated. I would think that for a typical black-and-white film the color of light for the border and surround is not nearly as important as it obviously would be for color film. It may be a function of the actual brightness to which the surround should be adjusted for optimal viewing conditions. It is possible that one color temperature will be desired for higher screen brightnesses, and another one for lower screen brightnesses.

Anon: I recall from several years ago that the Windermere Theater, on the Cleveland East Side, was a theater where auditorium illumination was on the high side compared with most theaters. Possibly you people have done some experimental work there. I was wondering if there were any theaters that you could point out or that you had in mind that do use a border brightness of somewhere around the figure that you quoted, that is, where, for example, with 10 ft-L from the screen you had a border brightness of about 0.5 ft-L?

Mr. Guth: I am not familiar with any

such theaters. Since I started thinking about this problem I have been very conscious of the border brightnesses and the surround brightnesses, but I haven't come across any that I would judge were quite that high. I have seen some of the theaters in Cleveland that seemed to have a somewhat higher border brightness than others, but I made no measurements.

Anon: I was thinking that it might be very interesting to actually see something like that, and if you could convince some neighborhood theater in Cleveland, they would experiment a little bit and I am sure there would be enough people in Cleveland glad to work with you on that.

Mr. Guth: It would be interesting to make such experiments. Ultimately, only full-scale investigations can give us the final answer regarding the desirable surround and border brightness.

Ben Schlanger: We have designed several theaters in which we have relatively high levels of illumination around the screen, by the synchronous method. Mr. Logan has had the opportunity to see one of them and I believe he refers to this example in his paper.

W. W. Lozier: I have two questions, Mr. Guth. One, your observations were all made at a point corresponding to the back of the average theater. I wonder how they might be changed for a person sitting up in the middle of the auditorium area or toward the front?

Mr. Guth: I don't have any actual data on that particular phase of it, though several observers did sit at various distances from the screen for a few observations. We found that with shorter observation distances the surround brightness became less important. However, the border brightness still remained important because of its proximity to the picture area. This brief test indicated that the border brightness was about the same, regardless of the observation distance. However, this should be confirmed by observation distances.

Dr. Lozier: Another question—you relate this border brightness that the observer shows to the average-picture brightness. Do you have any information on what their preference was on picture brightness? Was any preference expressed on that?

Mr. Guth: This is, of course, another aspect of the problem. With the available conditions, we obtained clear-screen brightnesses up to 60 ft-L, or an average-picture brightness of 6 ft-L. The preferred clear-screen brightness was discussed by the five observers and by others who viewed the test conditions, but did not participate in the test. They all preferred the higher screen brightnesses—something closer to 25 ft-L. I personally liked the 60 f-tL clear-screen brightness.

Dr. Lozier: In a theater with borders and surrounds covering as great a solid angle as you used, and with the high brightness you used, would there not be reflected in the audience area considerable light which would allow distraction?

Mr. Guth: The stray light from very high surround and border brightness may provide objectionable brightnesses in the audience area. This illustrates some of the practical problems that must be solved by studies in actual theaters.

O. E. Miller: I'd like to ask Mr. Guth if, in his experiments, he noticed any tendency to change the type of illusion that was created from the type that you get with no illuminated border around the screen? The reason I ask this is because I was involved in a few experiments some years ago with illuminated borders and have done some work in print illumination and transparency illumination, which seem to show that with an illuminated border the mode of appearance of the picture actually changes from that of a real scene to make it appear as if you were looking at a print. In other words, the actual mode of appearance changes.

Mr. Guth: That is correct if the border brightness is too high. The appearance of the picture and the created illusion were among the criteria used by the observers. They felt that if the border brightness was too high it affected the appearance of the picture. Even though there was no stray light upon the projected picture, the high border brightness did destroy the intended illusion. If they held the border brightness below a certain point, it had no noticeable effect. Of course, when one goes from a complete blackout to some brightness, an immediate change is obtained. However, over quite a range of brightnesses, there didn't seem to be too much effect upon the picture.

Photometric Factors in the Design of Motion Picture Auditoriums

By HENRY L. LOGAN

The photometric factors in designing the visual environment in a motion picture theater to promote the comfort, enjoyment and safety of the audience are discussed. The dependency relationship of screen surround and house brightnesses to screen brightnesses is explained. Optimum relationships are given and suggestions made for the practical execution of the recommendations, including the locations of lighting units and the shaping of the auditorium walls and ceilings.

THE PHOTOMETRIC factors of importance in the motion picture theater are the screen brightnesses with film running and their relationships with all the other brightnesses in the field of view that are necessary to promote the visual comfort, enjoyment and safety of the audience; and the brightness relationships without film running and full house lighting.

As all the difficulties arise with the former and not with the latter, this paper will be confined to the situation that exists with film running.

It will be found that a brightness distribution that accomplishes the goals just mentioned requires special handling of the screen and its adjacent surround, some modifications in the shape of auditoriums, predetermination of the percentage of light reflected from each part of the auditorium interior (and hence, determination of finishes) and precise control of the light emitted from the lighting equipment.

Up till now, the writer has had the impression that most motion picture theaters have been designed for their effect on the observer with full house lights on rather than for their effect when film is running.

With film running, motion picture screens average from 1 to 3 ft-L brightness. If we set the brightness relationships to meet the upper figure, we reduce the sensitivity of the eye to the darker portions of the film, even if we so light the theater that no house light can get back to the screen to reduce its contrasts. With auditoriums as they now exist, an overlay of diffused light on the screen is inevitable, which is one reason why house lighting is so little used when film is running.

Actually we are driven to take the least brightness that occurs on a black-and-white film as our starting point. This is about 0.04 ft-L and is the same brightness that Spragg has shown to be the minimum for satisfactory visual performance and safety.

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by Henry L. Logan, Holophane Company, Inc. (Illumination Service), 342 Madison Ave., New York 17, N.Y.

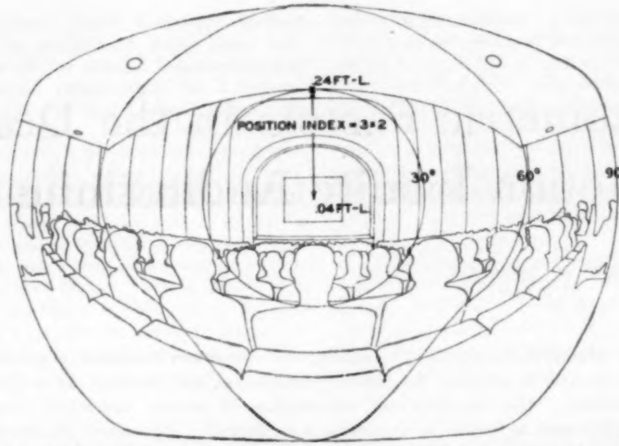


Fig. 1. Field of view of a patron seated in the standard observer's position, showing how the surround brightness 30° above the line of sight can be as much as six times the screen brightness by virtue of the position index relations.

Brightnesses located off the axis of vision have a lower-discomfort effect than similar on-the-axis brightnesses, as shown by the position-index data of Luckiesh and Guth,[1] and Harrison.[1a] Thus, the brightness of the surround adjacent to the screen can be greater than 0.04 ft-L without impairing the keenness of vision directed at the screen, and without introducing distraction.

For example, at a point 30° above the center of the screen the position index is 3, and if the line of sight is directed at the center of the screen, which has a night-scene running of 0.04 ft-L, the point 30° above the screen can have a brightness of 3 × 0.04 ft-L, or 0.12 ft-L, in order to produce a response equal to that caused by 0.04 ft-L screen brightness, provided the areas occupied are about equal (see Fig. 1).

The latest work of Guth (see the preceding paper in this JOURNAL) shows that acceptable off-axis brightnesses can be twice as great when the observer is engaged in purposeful seeing, than when he is looking at random. As there is no doubt that an observer looking at running film has his attention deeply engaged, the surround brightness at this point, 30° above the axis, can safely be 2 × 0.12, or about 0.25 ft-L. This should permit both keen vision and a high degree of visual comfort under the condition of minimum screen brightness common today.

Thus, the brightness of the screen surround can begin with 0.04 ft-L at the screen edge and increase gradually, in accord with the position indices for critical seeing, as we proceed away from the screen along walls and ceiling.

The areas occupied by the brightnesses are important and in practice the position indices, when used to guide permissible surround brightness, must be changed by a factor to compensate for differences in area of screen and the strips of surround brightness.

This is quite consistent with the writer's earlier findings,[2] which gave a level of 0.1 ft-L as the permissible maximum brightness within 30° of the observers' line of sight.

Earlier in this discussion it was stated that we are driven to take the least brightness, that occurs long enough to measure on a black-and-white sequence,

as our starting point. This is because the next logical criterion would be the overall average brightness of the darkest running film, or 1 ft-L, and it would lead us into detrimental surround brightnesses.

Theoretically it would permit a screen surround brightness of 6 ft-L (3 × 1 × 2) at the previously mentioned 30° point. Against that we have the definite finding of Jones[3] that a brightness of 3 ft-L is the highest that can be tolerated toward the front of an auditorium.

Recent research[4] shows that visual comfort for 100% of the audience is about $\frac{1}{3}$ of tolerance (meaning by tolerance, the comfort–discomfort threshold). Therefore, the maximum *comfortable* screen surround brightness would be 1 ft-L or only $\frac{1}{6}$ of the figure we arrive at by using the overall average brightness of the darkest running film. It is safest, therefore, to stick to the criterion previously discussed, namely, the lowest brightness that occurs long enough to measure in a black-and-white sequence.

Coming to the rest of the auditorium, recent work by Guth,[5] Petherbridge and Hopkinson[6] (and its development by the writer) shows that higher brightnesses are desirable in other parts of the auditorium than was previously thought.

Before proceeding to a discussion of these brightnesses, it might be well to point out that acceptable screen surround brightnesses can be secured by utilizing the reflected light from the screen, in the fashion developed by Schlanger. The method consists of framing the screen in a recess of sloping reveals that are bathed in light from the screen. These reveals start at the edges of the screen, from which the black frame margin is absent, and slope outward toward the remainder of the auditorium. Schlanger has carried this idea even farther, and has sloped all his auditorium surfaces so they favorably receive light from the screen and reflect it into the house. This has the effect of maintaining the adaptation level of the eyes

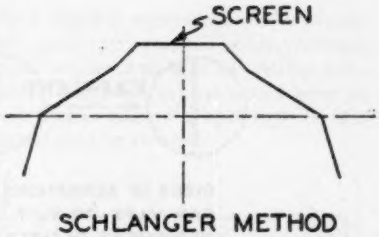


Fig. 2. Plan view of the proscenium and auditorium showing the relation between reveals and screen recommended by Schlanger.

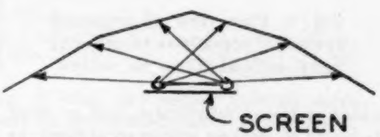


Fig. 3. Plan view of proposed reveal lighting arrangement, with light sources behind screen.

fairly close to that established by the screen, so that it is possible for a member of the audience to look all around such an auditorium, with the film running, and see comfortably well. Of course, high light-reflection factors are necessary, which restricts the range of decoration that can be used and gives the interior a somewhat severe aspect when house lights are on and film not running. Nevertheless, these interiors do give one the feeling that one is in an auditorium successfully designed for the showing of motion pictures to full advantage, and they impart a feeling of security to the observer that is lacking in most motion picture theaters.

The screen surround can also be properly lighted if the screen is set forward of similar reveals. The reveals, then, are lighted independently from sources behind the screen, either synchronously, varying along with screen brightness, or at a fixed level. For the fixed case, the reveals remain at the same brightness, independent of the fluctu-

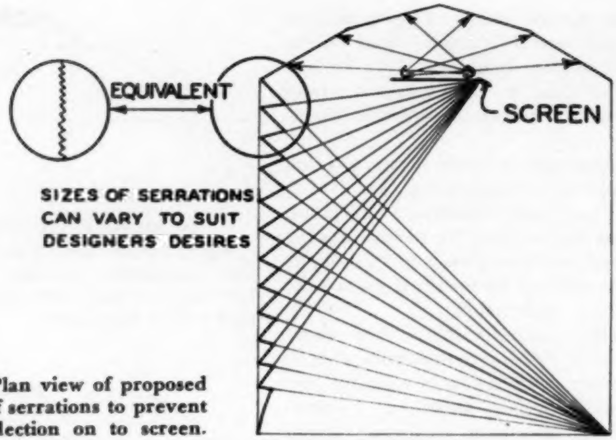


Fig. 4. Plan view of proposed system of serrations to prevent light reflection on to screen.

ations of screen brightness, and so must be keyed to darkest screen conditions, as explained. However, to prevent an overlay of light from the reveals onto the screen, the screen should be level with the front edges of the reveals, instead of, as in Schlanger's use of reveals, level with their back edges.

Returning to the subject of brightnesses in other parts of the auditorium, the sides of the auditorium at the proscenium end can start with a brightness of 0.25 ft-L, or, if the position indices do not permit, a lower value increasing to 0.25 ft-L which should be continued for about two-thirds the length of the auditorium. The walls of the back one-third can safely have a brightness of 0.5 ft-L.

The ceiling brightness should follow in the same way; 0.25 ft-L from the proscenium arch back for two-thirds of the ceiling, rising to 0.50 ft-L at the rear.

Brightness on the floor should be confined to the traffic aisles and the crossovers. Where aisle lights can be properly located and shielded from the eyes of the patrons, they provide a satisfactory solution. Another solution is downlights located and designed so as to light the aisles and crossovers only, and not spill light onto the audience. Floor brightnesses can start at 0.25 ft-L at front of auditorium, gradually rising to 1 ft-L on the rear crossover.

However, brightnesses at these levels will put a sufficient overlay of diffused light on the screen to interfere seriously with its clarity, unless the light is prevented from getting back to the screen.

One way to prevent it is to serrate the walls and ceilings; one face of each serration should be turned toward the audience and have a high light-reflection factor; the other face of each serration should be turned toward the screen and given a reflection factor of about 20%. These serrations can have various shapes, but a simple dogtooth section will work well.

In a rectangular auditorium both faces of the serrations would tend to be smaller toward the screen end, with the side facing the audience, larger toward the rear; while in an auditorium where the walls sloped in to meet the proscenium, the side of the serrations that faced the audience would be larger near the proscenium.

Various rhythms of size and shapes of the serrations are possible, depending upon the creative ability of the designer and the limitations in shape of the auditorium in question.

By using an absorbing finish on the faces of the serrations that face the screen, and reflecting finishes on the opposite faces, the walls can be lighted directly from the ceiling by lighting equipment running along and close to the walls. This equipment can be concealed by a variety of methods.

The ceiling will receive sufficient light by diffusion from the walls, but to have satisfactory brightness the reflecting faces of the ceiling serrations should be given a higher reflection factor than the reflecting faces of the wall serrations. However, they can be given a lower reflection factor if they are lighted independently from the walls. One way of doing this would be to make a horizontal break in the walls, say one-third down, providing a concealing ledge within which lighting equipment of the proper size and performance characteristics could be placed to light the ceiling indirectly. Such equipment would have to have perfect control as spill light on the walls should be avoided.

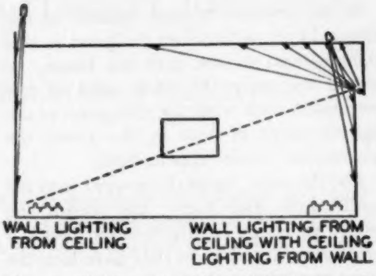


Fig. 5. Wall and ceiling lighting methods for desired surround illumination.

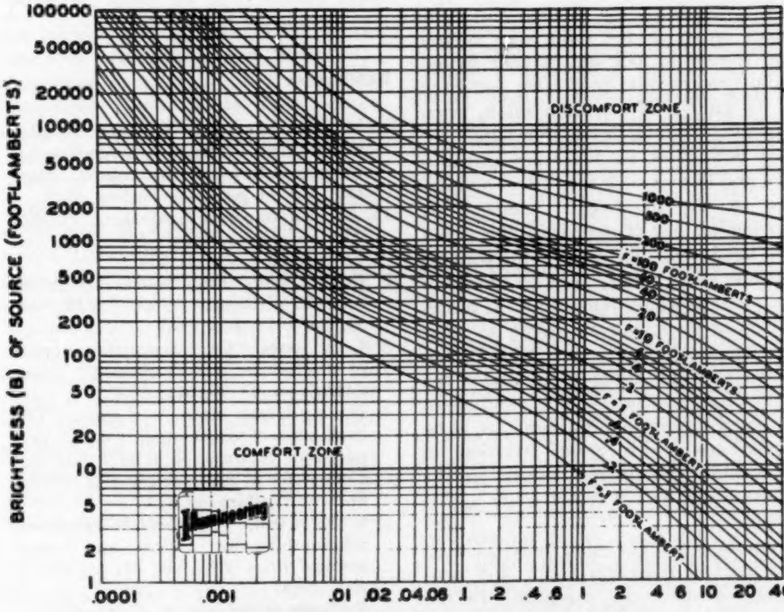


Fig. 6. Visual Comfort Chart—The comfort–discomfort threshold relations in terms of light source brightness, size and adaptation brightness. (Copyright 1951 Holophane Company, Inc.)

Finally, both the balcony face and the rear auditorium wall should be given the same reflection factor as the dark sides of the serrations, so that these surfaces, which face the screen, will not diffuse significant quantities of light to the screen.

If an observer placed himself at the screen in an auditorium designed in this fashion, and looked into the house, he would see only the dark sides of the serrations, and, with the exception of the lighted strips of floor in the aisles, the auditorium would appear dark.

On the other hand, if he went into the auditorium and faced the screen, he would see a well-lighted interior having a brightness distribution that gave him the same response as the darker sequences of the pictures. As he looked away from the screen, the auditorium would appear still brighter, and he would find it easy to look away from the picture and back again, in much the same way as you find it easy to look out of your living-room window onto your lawn and back to the interior of the room again, when daylight is coming through the window.

In both cases, the brightness distribution and level is such that visual adaptation is not significantly changed in moving the line of sight from the screen into the auditorium, or from the window into the living room. The sensitivity to the pictures would remain just as unimpaired as does your sensitivity to what you can see through the window, when sitting in your living room under the conditions described. The equipment, shapes of surfaces and finishes have to be worked out with great precision to accomplish the desired effects, as the effects occur only if *control of the light is complete.*

Colors of finishes must be selected on the basis of reflection factor and neutrality of observers' response. In the light of MacAdam's work (see his paper earlier in this Journal), care must be taken that the colors selected for the immediate screen surround do not distort the reception of Technicolor and Kodachrome in the eye. The aim is to provide a neutral surround to subordinate all elements in the theater to the projected image.

The entire screen surround and theater interior should be designed with modern illuminating engineering techniques and data borne in mind. Lighting proposals for theater interiors can be analyzed and carefully checked by the flux analysis method and evaluated with newly-developed visual-comfort criteria (shown in Fig. 6), to insure that the proposed interior will be found visually comfortable by 100% of an audience. In short, a complete design technique is now available that will permit experiments to be investigated on paper, with the outcome of the various proposals rather definitely determined at the paper stage, instead of at the client's expense after the theater is finished.

References

1. M. Luckiesh and S. K. Guth, "Brightnesses in visual field at borderline between comfort and discomfort," *Illum. Eng.*, vol. 44, pp. 650–670, Nov. 1949.

1a. W. Harrison and P. Meaker, "Further data on glare ratings," *Illum. Eng.*, vol. 42, pp. 153–179, Feb. 1947.

2. H. L. Logan, "Brightness and illumination requirements," *Jour. SMPE*, vol. 51, pp. 1–12, July 1948.

3. L. A. Jones, "The interior illumination of the motion picture theatre," *Trans. SMPE*, pp. 83–96, May 1920.

4. H. L. Logan and A. Lange, "The evaluation of visual comfort data," prepared for presentation at 1951 National Conference of Illuminating Engineering Society, Washington, D.C.

5. S. K. Guth, "Comfortable brightness relationships for critical and casual seeing," *Illum. Eng.*, vol. 46, pp. 65–75, Feb. 1951.

6. P. Petherbridge and R. G. Hopkinson, "Discomfort glare and the lighting of buildings," *Trans. Illum. Eng. Soc.* (*London*), vol. XV, No. 2, pp. 39–79, 1950.

New Approaches Developed by Relating Film Production Techniques to Theater Exhibition

By BENJAMIN SCHLANGER and WILLIAM A. HOFFBERG

A larger screen, camera angles, factors of psychophysical vision and auditorium viewing are considered relative to the development of more flexible screen cinematography. Screen masking, surround and auditorium environment are also considered.

It is gratifying to report at this time the increasing recognition of the significance of auditorium and screen environment in relation to greater film enjoyment. There is also now a more ready acceptance of larger screens. These developments are due to the increased use of color film and the competition of television. The disadvantages of a dark auditorium and screen environment have become apparent due to the recognition of the resulting visual fatigue and the essential unpleasantness of blackness; color film accentuates this. The Symposium on Screen Viewing Factors, to which this paper is a contribution, concerns itself with the above scope and is in itself evidence of a trend.

Since our last paper presented to this Society in October 1950,[1] we have made further studies which now enable us to make some definite recommendations for a dramatic improvement in motion picture exhibition in theaters. We now propose a substantial increase in the size of theater screens together with a new use of the increased areas beyond present picture sizes. The added screen area should be devoted to peripheral and interpretive cinematography as well as occasional use of the entire screen area for clearly defined images. This proposed exploitation of the additional screen area is of intrinsic importance.

The advocacy and use of large screens has a long history. However, within the last 20 years, improvements in film grain reduction, studio set lighting and the increase of projection light intensity have now made the large screen feasible. Certainly the novelty factor of sound which was introduced about 1927, when large screen trials were made, has now been dissipated. A major fault of the early large screen attempts was the absence of a cinematography consistent with wide-angle viewing in theaters. As a result, the audience experienced the annoyance of moving their eyes to follow the extreme positions of action and the

Presented on May 2, 1951, at the Society's Convention Screen Viewing Factors Symposium, at New York, by Benjamin Schlanger and William A. Hoffberg, Theater Engineering and Architecture Consultants, 35 W. 53d St., New York 19.

Figure 1

constant doubt as to whether they were looking at the center of concentration.

In our opinion, the effective use of the large screen is made possible by the following suggested production and exhibition techniques:

Flexible Cinematography

By using the larger screen as a palette, a more flexible cinematography is made possible. The present aspect ratio (width: height) of 8.25:6.0 is a straight-jacket for the cinematographer since various scenes require varying aspect ratios. By the use of darker vignettes, the cinematographer at present can vary his shape but he must sacrifice valuable screen area, as observed by Lewis W. Physioc in 1931, who wrote: "Vignetting and other effects are prohibited by the limited areas."[2] The use of light vignettes is comparatively rare because existing screen surround treatments are invariably dark.

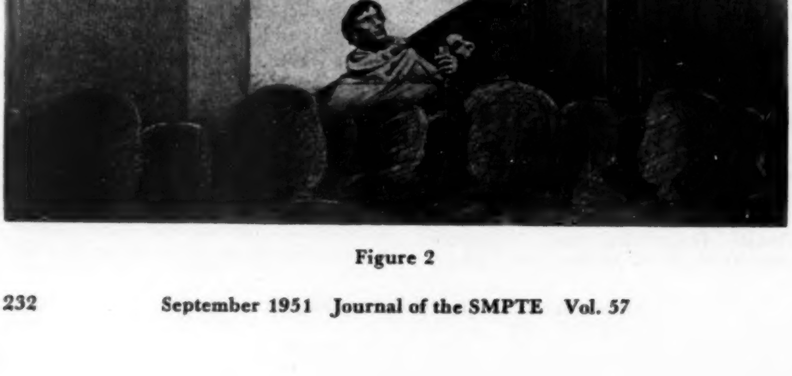


Figure 2

Figure 1 depicts a present screen in the usual dark theater as viewed from a distance of about 90 ft from the screen, which is 5 times the screen width of 18 ft. Figure 2 is taken from the same viewing distance of 90 ft and shows the effect with a 30-ft screen; the viewing distance is thus 3 times the screen width. The size of the head in the picture is the same in both illustrations but Fig. 2 illustrates a light vignette extending into a light screen surround and a dark vignette extending into a dark screen surround. As a result, there is no apparent aspect ratio or confining frame. The effects shown in Fig. 2 have heretofore been impossible to achieve.

Synchronous, Luminous Peripheral Extensions

The larger screen would be used for clearly defined picture content and vignetted as well as peripheral extensional surrounds. All of the desired effects would be on the 35-mm film. The cameraman will have designated on his view-finder the boundaries of clearly defined detail area. This area will vary in size and shape to suit the requirements of the scene. The props, background and people located in the portions beyond the clearly defined area will be recorded on the film only to establish light intensity and color, thus forming an atmospheric extension of the detailed picture.

By the use of diminished lighting or increased lighting in the periphery, for interior shots, the outer areas are recorded as vignettes which diffuse to light as well as dark terminations. For certain interior shots and most exterior shots, it will be more appropriate to use diffusing tonal extensions which will be obtained by placing in the camera or in the optical printer a filter which has an open area equivalent to the defined picture area. The above filter is placed at a distance from the sensitized film so as to establish an amount of diffusion which will create color and light intensity extension with or without identifiable detail. The vignettes and peripheral extensions would always automatically *synchronize* with the detailed portion of the picture.

Picture Shape

In 1929, L. A. Jones[3] made some very pertinent observations regarding various aspect ratios. He came to the conclusion that it is impossible to get a standard proportion which will satisfy the variety of forms of compositional construction. He found that for landscape and mass compositions the most favorable ratio of width: height ranged from 1.55 to 1.60 but for portrait compositions this ratio varied from 0.88 to 1.48. This indicates the great difficulty in fixing a constant aspect ratio in cinematography. Flexibility of shape offers a solution. Not only should there exist the ability to vary the proportions of the rectangle but there should also be the possibility of using any other shape. It is also significant that it is possible to dissolve the sense of shape by the use of luminous as well as darkened vignettes and thus achieve a "shapeless shape."

Use of Wide Angle Lenses

There has been a marked trend since 1939 toward the increased use of wide-angle lenses in film production. Prior to this date, the use of a 25-mm lens with a camera angle of 47.5° was exceptional. In 1928, A. C. Hardy and R. W. Conant[4] stated that to avoid perspective distortions in theater viewing, the correct location is obtained by multiplying the projection distance in the theater by the ratio of the focal length of the camera lens to the focal length of the projection lens. With a camera lens of 2-in. focal length and projection lens of 4-in. focal length, as determined by present screen size, the best viewing position would therefore be at a distance from the screen equal to one-half the distance from the projector to the screen. With a 1-in. camera lens and 4-in. projector lens,

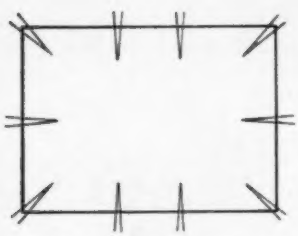


Figure 3

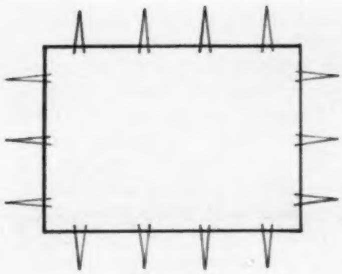


Figure 4

the best viewing position would be at one-fourth the distance from projector to screen. The increased use of wide-angle lenses therefore has a detrimental effect on the best viewing position in the theater since it throws this point too far forward, namely about in the third row orchestra.

With the recommended use of the larger screen, the focal length of the projection lens would be reduced to about 2.5 in. and with a 1-in. camera lens, the best viewing position would be at two-fifths of projector to screen distance or about the tenth row orchestra. The change to larger screens is consistent with the already increased use of wide-angle camera lenses.

Occasional Use of Full Screen

Although we propose that the detailed picture area will occupy varying amounts of the total screen area for the major portion of the time, it is possible and advisable for climactic, tonic and panoramic scenes to use a maximum of the entire screen surface. This occasional use of the entire screen, which is all produced on the film, does not require the expensive and cumbersome mechanical spreading devices for the screen masking.

Effective Use of Screen Area

It is important to observe that in present cinematographic practice there is a tendency to "play safe" by avoiding the use of the marginal areas of the screen. Figure 3 is intended to express the diagrammatic force of pictorial composition as influenced by the usual black masking and dark screen surround. By way of contrast, in Fig. 4 is the expression of the relative effect of an outward force which becomes possible with the synchronized extension in light, shade and hue as previously described. The ability to extend important detail and effects up to the extreme edges of the detailed picture increases the effective area of the picture.

Visual Experience in the Peripheral Zone

Psychological as well as physiological factors must be evaluated in order to analyze visual experience. Little consideration has been given heretofore to the problem of expressing the effects which occur in the peripheral zone. Figure 5 represents the portion of the field of view occupied by the camera angle of a wide-angle lens of 1-in. focal length. This angle of 47.5° includes varying angles of peripheral experience. Figure 6 indicates the portion of the field of view of the spectator in the theater from the furthest and closest seats, as expressed by the ratio of viewing distance to width of picture and shown as $5W$ and $1W$. The proportion of the field of view occupied by the screen from the average viewing position is far less than the widest camera angle and occupies much too small a segment of the total field of view.

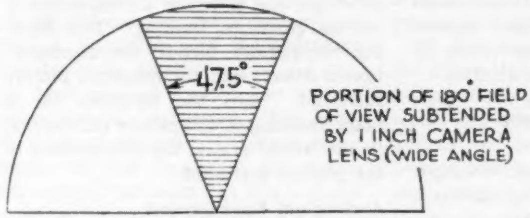


Figure 5

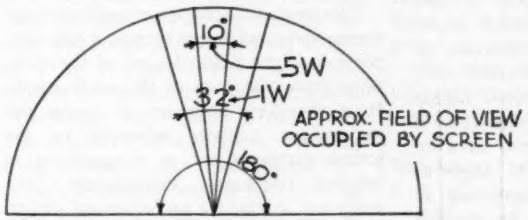


Fig. 6. Field of view in existing theaters.

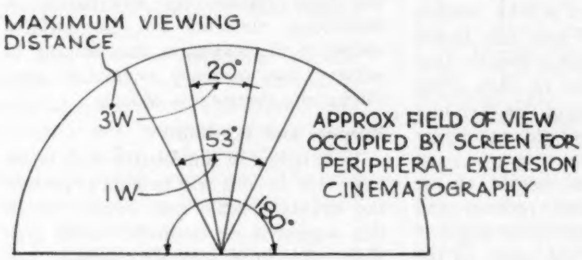


Fig. 7. Field of view as recommended.

Figure 7 indicates the proposed increase in screen size and its effects on the proportion of the spectator's field of view as seen from $3W$ and $1W$. It becomes evident that, with the increasing use of wider angle camera lenses up to 1-in. focal length, the screen in the theater should subtend an angle consistent with camera angles. A synchronized luminous field surrounding the projected picture, as hereinafter described, subtends a still greater angle into the peripheral zone.

Concentration and Diffusion in the Field of View

It is most significant that the portion of the field of view of the human eye, which appears less distinct and almost obscured, varies considerably with the amount of concentration experienced at any given moment. The angle of clear vision detail discernment *narrows* as the degree of concentration increases. In direct contrast with this, when there is least reason for concentration, as in a panoramic view, we seem to see a maximum of the total field in more or less clearly defined detail. The viewer is hardly aware of the slight movements of the eye muscles which enable him to encompass the panorama clearly.

As concentration increases in intensity, the angle of clear vision decreases and the degree of *diffusion* of detail outside of this zone increases. These observations offer the clues as to how best to interpret cinematographically these experiences and help to determine the types of vignettes and filters to be employed. For example, in an interior shot where intense concentration occurs,

the vignetting process will diffuse detail at a point close to the main interest and extend therefrom into areas of light or shadow as the scene dictates.

Synchronous, Luminous Screen Surround

Even the recommended enlarged screen does not occupy a sufficient portion of the spectator's field of view in the theater. The subtended angles to the screen at viewing distances of $1W$, $2W$ and $3W$ are respectively 53°, 28° and 19°. It is therefore highly desirable to extend the sensation of luminosity beyond the screen area so that the resultant subtended angle of the total luminous field consisting of screen and screen surround approaches the subtended angle of a 1-in. camera lens. We have found that this screen surround luminosity must be synchronous with the light intensity of each scene and, with color, the hue of this surround must be an extension of the colors in a scene.

The screen surround begins at the edge of the projected picture and extends to the audience at an angle of approximately 45° to the plane of the screen. It has a slight concave curvature toward the audience in order to control gradations of light shading which are synchronous reflections of the projected picture. The surface of the surround usually consists of a diffusive finish. The dimensions of the screen surround will vary with the size of the picture and the size and shape of the auditorium, similar to installations recently made by us in the Crown Theatre, New Haven, Conn., and the Shopping Center Theatre, Framingham, Mass.

It is, of course, mandatory to provide a proper transition between the projected screen image and the luminous surround because of the fuzziness, color aberration and image movement discernible at the edges. We have solved this problem by the use of a translucent plastic material located so as to overlap the edges and to reveal a comparatively narrow luminous framing. This framing successfully blends the aforementioned defects into the luminous picture surround. Thus the necessity for a black masking is completely eliminated; its use would negate the effectiveness of the picture surround.

Auditorium Environment

The proposed screen size and luminous screen surround do not occupy a sufficient portion of the field of view of the spectator from the rear of the auditorium. It is therefore necessary to make the auditorium surfaces adjacent to the screen surround act as a transition to relative darkness. Fortunately, the tendency in theater architectural design has been toward the elimination of distracting elements on the surfaces visible to the audience, thus helping to achieve the necessary neutrality, simplicity and destruction of scale.

Purpose and Feasibility

1. It is highly improbable that home television viewing will be able to present the dramatic scale and impact which this suggested development makes possible. An important step would thus be achieved toward re-establishing the motion picture theater as a unique medium of entertainment.

2. This development provides new tools and techniques which help remove some of the shackles which have long hampered the cinematographer.

3. It provides an atmospheric extension of picture light, shade and color which is more closely related to visual experience. Certainly, the removal of the black surround for color pictures is much to be desired.

4. It is generally conceded that the reduction of contrast between picture-light intensity and surround-light intensity will reduce visual fatigue and we further contend that synchronization of the surround and picture lighting will more successfully reduce this contrast.

5. The ability to place important action in remote positions of the enlarged screen is consistent with the objectives of stereophonic sound.

6. Most existing theaters can accommodate the enlarged screen. The sightline clearances in some theaters will not include the full height of the screen from some of the seats but this will not be serious because the obstructed areas of the enlarged screen will usually be within the zones of atmospheric extension. The enlarged screen would be placed as low as possible with the intent of destroying the rigid horizontal line at the bottom of the picture. Existing seating patterns and distance to the first row of seating would not have to be changed since the entire enlarged screen is used for sharply defined images only occasionally.

7. The cost of adapting existing theaters to this system is limited to providing a new screen and the surround treatment, new projection lenses and, in some instances, new projection lamphouses and wiring provisions. The only additional operating cost is the increased current consumption.

8. This development does not require any radical change in production equipment. The minor modifications necessary to effect the vignetting and diffusing characteristics herein proposed should not be costly.

9. Although this development lends itself admirably to any increase in film width, it is feasible with the use of 35-mm film since the image enlargement which is required is similar to many large screens now in use.

10. For new film productions using the above techniques, it is an important feature that separate prints can be made which are adapted for use on existing screens by printing only the clearly defined image for the entire film width and omitting the peripheral extensions. It is also possible to reprint existing films by the use of filters in the optical printer to simulate the desired effects.

The early feasibility of this proposal was accented in all of the above research and development.

References

1. B. Schlanger and W. A. Hoffberg, "Effects of television on the motion picture theater," *Jour. SMPTE*, vol. 56, pp. 39–43, Jan. 1951.
2. L. W. Physioc, "Problems of the cameraman," *Jour. SMPE*, vol. 17, pp. 406–416, Sept. 1931.
3. L. A. Jones, Bulletin No. 410 of the Kodak Scientific Research Laboratory, Rochester, N.Y., 1929.
4. A. C. Hardy and R. W. Conant, "Perspective considerations in taking and projecting motion pictures," *Trans. SMPE*, vol. 12, no. 33, pp. 117–125, 1928.
5. B. Schlanger, "Increasing the effectiveness of motion picture presentation," *Jour. SMPE*, vol. 50, pp. 367–373, Apr. 1948.
6. B. Schlanger, "On the relation between the shape of the projected picture, the areas of vision, and the cinematographic technic," *Jour. SMPE*, vol. 24, pp. 402–409, May 1935.

Report on Screen Brightness Committee Theater Survey

By W. W. LOZIER, Committee Chairman

A PRELIMINARY survey of 18 theaters by the Screen Brightness Committee in 1947[1] disclosed interesting indications of theater screen illumination practice in this country, but was inconclusive because the theaters covered represented too limited a sampling. A more extensive survey was not carried out at that time because of the lack of a suitable meter. More recently, the General Electric Company placed at the disposal of the Committee a meter which is better adapted to a theater survey. Consequently, during the summer of 1950, the Screen Brightness Committee of the Society undertook a survey of screen illumination and related factors in 100 representative indoor theaters. It was the Committee's purpose in this larger survey to cover a more representative segment of the theaters in this country and to obtain dependable data concerning their practices, with the underlying thought that observation and discussion of any undesirable conditions would promote better projection. At the present time, results are available on 125 theaters, representing all except the Southeast and Pacific sections of the United States. It is believed that these results would not be greatly changed by representative coverage of these additional areas.

During the course of this survey, the Motion Picture Research Council became interested in carrying out a parallel survey in the West Coast studio review rooms used for viewing 35-mm pictures. Through their cooperation, we are able to include in this report the results on 18 review rooms.

Methods and Instruments

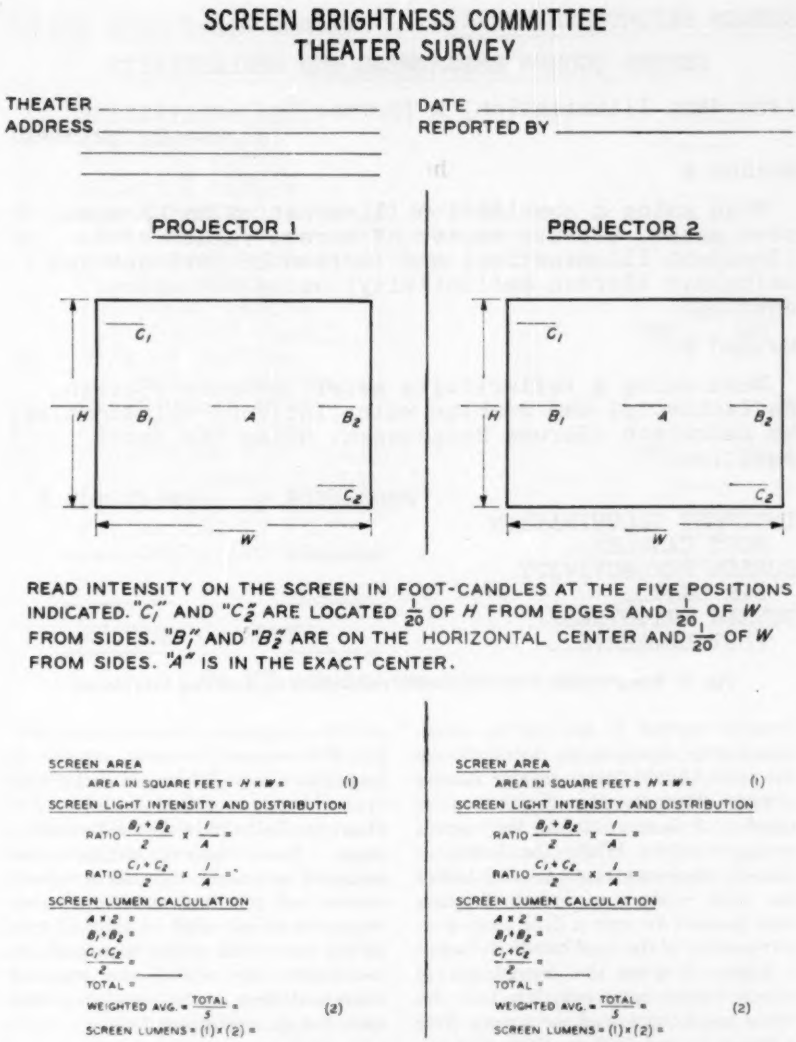
In contrast with the previous survey, all of the measurements in the present survey were made with an objective-type instrument requiring no visual photometric balance. Nearly all of the measurements were made with the two-cell General Electric combination screen illumination–screen brightness meter. A few measurements were made employing a simple foot-candle meter in combination with an improvised device for measuring the screen reflectivity.[2]

Data forms were simplified somewhat from those used in the 1947 survey and are illustrated in Figs. 1 to 3.

Classes of Theaters Surveyed

The 1947 survey was heavily weighted by the large downtown theaters in large cities. An effort was made in this survey

Presented on May 2, 1951, at the Society's Convention at New York, as a preliminary progress report on the first 88 theaters of this survey, by W. W. Lozier, Committee Chairman, Carbon Products Service Dept., National Carbon Company, Division of Union Carbide and Carbon Corp., Fostoria, Ohio.



SCREEN BRIGHTNESS COMMITTEE
THEATER SURVEY

THEATER ______ DATE ______
ADDRESS ______ REPORTED BY ______

PROJECTOR 1

PROJECTOR 2

C_1 H B_1 A B_2 C_2 W

READ INTENSITY ON THE SCREEN IN FOOT-CANDLES AT THE FIVE POSITIONS INDICATED. "C_1" AND "C_2" ARE LOCATED $\frac{1}{20}$ OF H FROM EDGES AND $\frac{1}{20}$ OF W FROM SIDES. "B_1" AND "B_2" ARE ON THE HORIZONTAL CENTER AND $\frac{1}{20}$ OF W FROM SIDES. "A" IS IN THE EXACT CENTER.

SCREEN AREA

AREA IN SQUARE FEET = $H \times W$ = (1)

SCREEN LIGHT INTENSITY AND DISTRIBUTION

RATIO $\frac{B_1 + B_2}{2} \times \frac{1}{A}$ =

RATIO $\frac{C_1 + C_2}{2} \times \frac{1}{A}$ =

SCREEN LUMEN CALCULATION

$A \times 2$ =

$B_1 + B_2$ =

$\frac{C_1 + C_2}{2}$ =

TOTAL =

WEIGHTED AVG. = $\frac{\text{TOTAL}}{5}$ = (2)

SCREEN LUMENS = (1) × (2) =

Fig. 1. Sample data form for incident screen illumination.

to cover a wider range of types and sizes of indoor theaters. Figure 4 shows the distribution of seating capacities among the 125 theaters surveyed. It also shows the distribution of seating capacities among the indoor theaters of the United States expressed both on the basis of percentage of theaters in various seating ranges and also as the percentage of the total theater seating capacity falling in the different seating-capacity ranges. It is seen that the distribution of

SCREEN BRIGHTNESS SURVEY

CENTER SCREEN BRIGHTNESS AND REFLECTIVITY

(Incident Illumination) x (Screen Reflectivity) = (Screen Brightness)

Method A

When using a combination illumination and brightness meter, measure center of screen values of (Incident Illumination) and (Screen Brightness) and calculate (Screen Reflectivity) using the above equation.

Method B

When using a reflectivity meter, measure (Screen Reflectivity) and combine with (Incident Illumination) to calculate (Screen Brightness) using the above equation.

	PROJECTOR 1	PROJECTOR 2
INCIDENT ILLUMINATION FOOT CANDLES___	_______	_______
SCREEN REFLECTIVITY PER CENT___	_______	_______
SCREEN BRIGHTNESS FOOT LAMBERTS___	_______	_______

Fig. 2. Sample data form for screen reflectivity and screen brightness.

theaters covered in our survey corresponds more closely to the distribution of the total United States theater seating capacity than to the distribution of number of theaters among the various seating ranges. While the less-than-500-seat theaters account for over half of the total number of indoor theaters, they account for only a little more than one-quarter of the total number of seats.

Figure 5 gives the distribution of screen widths measured thus far. All but a small fraction of the screens were between 14 and 24 ft in width, with the average at approximately 18 to 20 ft.

Screen Brightness

The distributions of screen brightness encountered with 36 review-room projectors and 245 indoor-theater projectors are given in Fig. 6. The present ASA standard limits, also shown in Fig. 6, call for a brightness between 9 and 14 ft-L. The indoor theaters ranged in brightness from 3.4 to 53 ft-L, with approximately one-quarter below and about one-half within the ASA standard range. Two theaters which were equipped with highly directional "silver" screens had a central maximum screen brightness in the range of 30 to 53 ft-L. In the case of the review rooms, almost two-thirds were within the standard limits and most of the remaining third exceeded the maximum limit.

Distribution of Illumination Over Screen

Figure 7 shows the distribution of illumination over the screen expressed as a ratio of side-to-center intensity of incident illumination. Side distribution ranged from 40% to 94% for the indoor theaters with approximately 85% of the projectors falling between 50% and 80%

SCREEN BRIGHTNESS SURVEY

PROJECTION DATA

1.	PROJECTION ANGLE	____
2.	ARC LAMP TYPE	____
3.	POSITIVE CARBON	____
4.	NEGATIVE CARBON	____
5.	ARC AMPERES	____
6.	ARC VOLTS	____
7.	PROJECTION LENS	____
	(a) f/ NUMBER	____
	(b) FOCAL LENGTH	____
	(c) SURFACE COATED	YES ___ NO
8.	TYPE OF SHUTTER	
	(a) DEGREE OPENING	____
9.	DRAFT GLASS TYPE	____
10.	HEAT FILTER TYPE	____
11.	PROJECTION PORT GLASS	YES ___ NO
12.	TYPE OF POWER SUPPLY	____
	(a) RATING IN AMPERES	____
	(b) RATING IN VOLTS	____
	(c) OPERATING VOLTAGE	____

AUDITORIUM DATA

1.	SEATING CAPACITY	____

Fig. 3. Sample data form for theater data.

distribution ratios. The most frequent distribution ratio fell between 60% and 70%.

The review rooms differ radically from the indoor theaters by having a much more uniform distribution of illumination over the screen. Of the review-room projectors 85% produced a side distribution between 80% and 100%. This more uniform screen distribution reflects the review-room problem of small screen size and excess illumination; defocusing the light source to produce a uniform distribution is one way which has been used to reduce excess screen brightness. It means, however, that motion pictures are viewed in these review rooms under conditions very different from those prevaling in motion picture theaters.

Figure 8 gives similar information on the ratio of corner-to-center incident intensity. Corner distributions are, in each case, approximately 10% to 15% lower than the side distribution and ranged from 26% to 83%. Figure 8 shows, however, the same basic pattern as Fig. 7.

Screen Reflectivity

Less than half of the indoor theater screens had reflectivities in the 70% to 80% range, typical of a matte white screen in good condition. Over 40% of the screens ranged from 70% down to 32% reflectivity. Approximately 10% of the screens had reflectivities between 80% and 100%. Five "silver" screens were in the range of 150% to 250%. A total of eight "silver" screens are included in Fig. 9.

The review-room screens, on the aver-

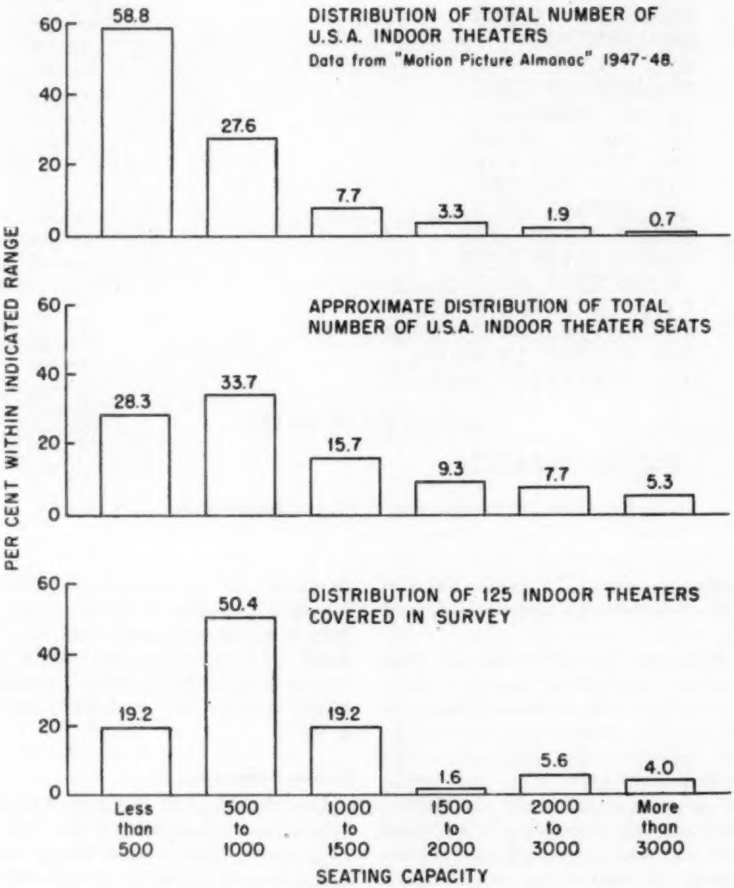


Fig. 4. Analysis of seating capacities of survey theaters and total United States indoor theaters.

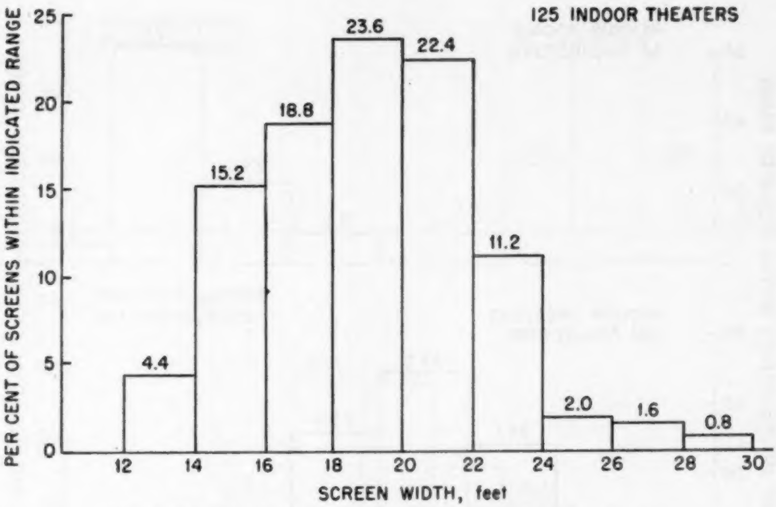


Fig. 5. Distribution of screen widths covered in the survey.

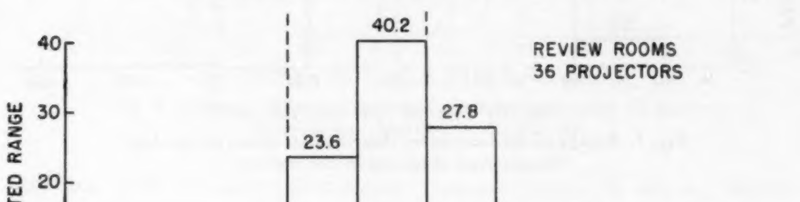


Fig. 6. Distribution of screen brightness obtained in the survey.

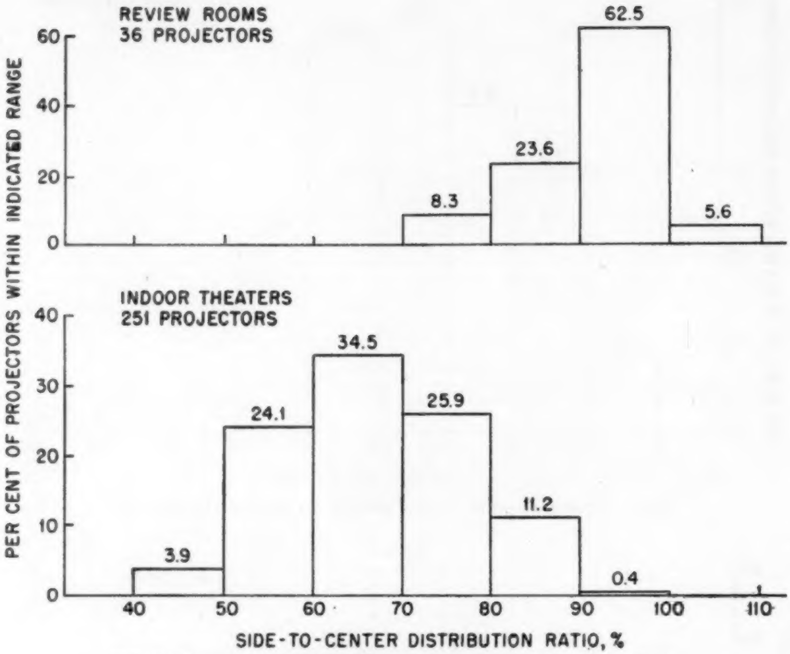


Fig. 7. Range of side-to-center distribution ratios of incident illumination obtained in the survey.

age, tended to have lower reflectivities than the indoor theaters, but not as great a range of extremes. This may again reflect the problem of excess illumination and the fact that even a deteriorated screen will produce adequate brightness with the small-size screens employed. However, if the low reflectivity is the result of deterioration, then such screens may also have undergone color change with resultant distortion of color motion pictures.

Summary

This survey of 125 indoor theaters has shown that the screen brightness falls within the recommended range for a little over half of the projectors, but that almost one-quarter of the theaters are below the recommended standards. The distribution of illumination over the indoor theater screens ranges from very uniform to extremely nonuniform. Screen reflectivity for the indoor theaters ranges from values typical of screens in good condition all the way down to values representing over 50% deterioration.

The West Coast review rooms generally show screen brightness within or a little above the recommended standards for indoor theaters. However, the review rooms differ from indoor theaters in having exceptionally uniform distribution of illumination over the screen. Review-room screen reflectivities show a lower average value than, but not nearly as great a spread of extreme values as, the indoor theater screens.

Compared to the 1947 preliminary survey, the present one shows an even wider range of screen brightness values,

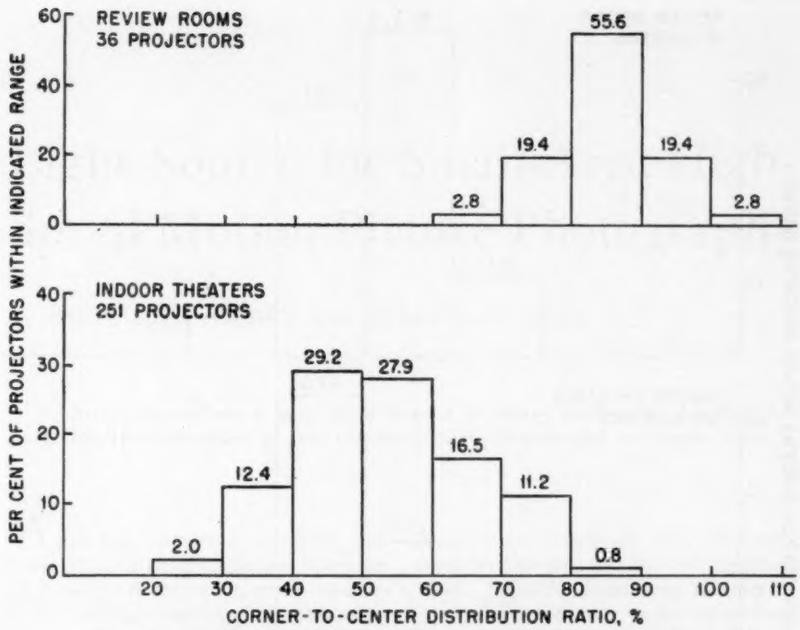


Fig. 8. Range of corner-to-center distribution ratios of incident illumination obtained in the survey.

but only about one-half as great a proportion of theaters below the recommended minimum brightness. Other factors studied, such as side and corner screen distribution ratio, cover approximately the same ranges as observed in the earlier survey. The screen reflectivities extend over a much wider range, including both some exceptionally low values and also a number of "silver" screens of extremely high reflectivity.

Recommendation

It is expected that the results of this survey will assist in the formulation of an eventual Committee recommendation for improvement of projection practice in theaters. In the meantime, however, it is believed that better attention to details of operation and maintenance can reduce the wide range of screen brightness observed and eliminate many of the extreme values. It can also eliminate many of the highly nonuniform distributions of illumination over the screen and thereby remove some of the objectionable conditions prevalent.

The findings of this survey in the West Coast review rooms are being considered by the Motion Picture Research Council and West Coast studios in relation to their program of improving review-room practices.

Acknowledgments

The Screen Brightness Committee and the Society are indebted to many people for assistance in the conduction of this survey. Theater projectionists, and their organization the IATSE, various trade publications and theater managers have been most cooperative in making their facilities and assistance available to us. Particular thanks are due to C. W.

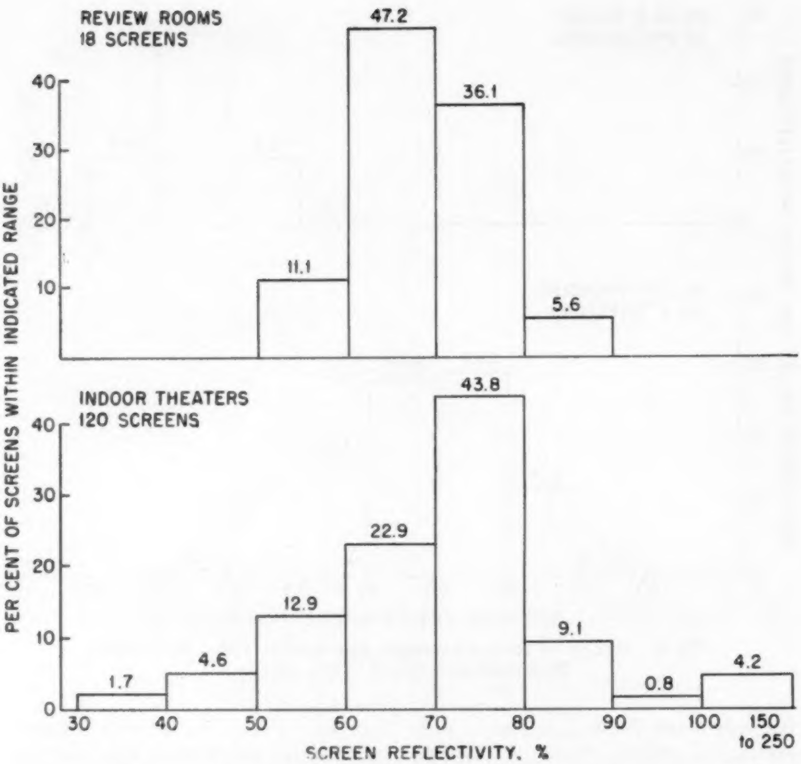


Fig. 9. Range of screen reflectivities obtained in the survey.

Handley, C. E. Heppberger and P. D. Ries of the National Carbon Company, A. J. Hatch of Strong Electric Corp. and C. R. Underhill of RCA for supervising and carrying out much of the survey work in the different areas of the United States. The Motion Picture Research Council took the initiative in obtaining the data on the West Coast review rooms. Without the fine cooperation of these individuals and groups, this survey would have been difficult if not impossible.

References

1. E. R. Geib, Chairman, "Report of Screen Brightness Committee," *Jour. SMPE*, vol. 50, pp. 260–273, Mar. 1948.
2. W. W. Lozier, Chairman, "Screen Brightness Committee Report," *Jour. SMPTE*, vol. 54, pp. 756–757, June 1950.

The Committee

W. W. Lozier, *Chairman*

Herbert Barnett	F. J. Kolb
H. J. Benham	W. F. Little
F. E. Carlson	L. J. Patton
M. H. Chamberlin	Leonard Satz
E. R. Geib	J. W. Servies
L. T. Goldsmith	B. A. Silard
L. D. Grignon	Allen Stimson
A. J. Hatch, Jr.	C. R. Underhill, Jr.
L. B. Isaac	H. E. White
W. F. Kelley	A. T. Williams
	D. L. Williams

Light Source for Small-Area High-Speed Motion Picture Photography

By RICHARD I. DERBY and ARTHUR B. NEEB

An illuminant which may be of interest to others working in this field has been assembled to give extremely high intensity for small-area use.

With the advent of the G.E. No. 750R-40 lamp designed for use primarily in high-speed motion picture photography, a large number of lighting problems have been greatly aided or solved.

In this laboratory, a lighting problem arose in which an area of about 2 to 3 sq in. was to be illuminated with such intensity as to obtain a field depth of about 2 in. at the minimum subject–lens distance. The light source to be described consists of one lamp and allows the use of Super X (not XX) film with a normal exposure index of 32 tungsten at *f*/10 using a 102-mm lens and a film speed of 3120 frames/sec, with a subject of medium reflectance (about 30%).

The source simply consists of one sealed-beam Par 64 No. 4560 G.E. lamp normally used as an airplane-wing light for illumination during night landing. The 28-v, 600-w lamp receives its power through a 20-amp variable transformer set at 30 to 33 v; this will no doubt decrease the lamp's normal life of 25 hr.

In conjunction with the lamp, a 6-in. planoconvex condenser lens, borrowed from an Omega type DII enlarger, was used. With the transformer set at some low voltage, the lamp was set up at about 3 to 4 ft from the subject while the condenser was aligned at 6 to 10 in. from the subject according to the desired dimension of the spot and its intensity. Full voltage was applied only during actual exposure.

The lamp was mounted easily in a short metal tube of the proper diameter, with a narrow flange rolled in on one end, against which the lamp is held by a Bakelite strip. The strip was fitted across the open end of the tube and attached by means of spring clips and pins. A mounting bracket spot-welded to the tube allows the assembly to be placed on a standard lamp stand. The condenser lens used with the lamp is fastened in a tube with a split retainer ring holding the glass against a flange rolled into the end of the tube.

A mounting bracket is fastened to the assembly so that it can also be used on a stand.

One must naturally take into consideration the great amount of energy in the form of heat which will impinge on

A contribution submitted July 11, 1951, by Richard I. Derby and Arthur B. Neeb, Research Dept., General Mills, Inc., 2010 E. Hennepin Ave., Minneapolis 13, Minn.

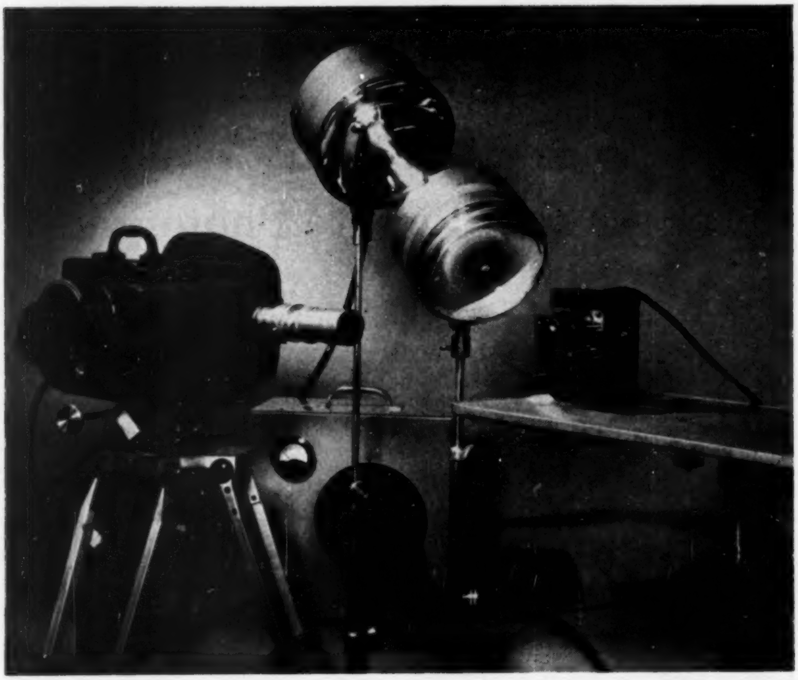


Fig. 1. Setup using the PAR 64 bulb and a condenser. The voltage to the bulb is controlled by a 20-amp variac as shown.

the subject during exposure. Many machining operations, where moving metal parts dissipate the heat, as well as clear plastics, which do not generally absorb a damaging amount of heat during the short exposure interval, can be photographed with this light. Small, rapidly moving subjects which pass through the illuminated area are, of course, a natural for this light source.

Exceptionally clear, crisp pictures can be obtained with this lamp because of the smaller lens opening and finer-grained films its use permits.

Figure 1 shows the setup using the Par 64 bulb and a condenser.

Dynamic Transfer Characteristic of a Television Film Camera Chain

By W. K. GRIMWOOD and T. G. VEAL

The relation between kinescope luminance and the illuminance on the mosaic of the iconoscope can be measured under operating conditions by the use of specially prepared slides or 16-mm films. One or more small areas in any selected scene are replaced by areas of uniform density. A series of slides or a complete film consists of a series of pictures which are all identical except for the density of these measuring areas. The television chain is adjusted for satisfactory reproduction of the scene. Measurements of the illuminances on the iconoscope in the aforementioned areas are then plotted against measurements of the kinescope luminances in the corresponding areas.

A number of transfer-characteristic curves are shown as examples of the effects of such variables as the density of the picture background, the shading control settings and the illuminance level. The differences between still and intermittent projection are illustrated by a set of transfer curves. Another group of curves shows the transfer characteristic of the photographic process, the transfer characteristic of the televising process, and the transfer characteristic of the combined film-television process.

Because of the dependence of the transfer characteristic upon the nature of the scene, no single characteristic can be considered as representing the performance of an iconoscope film camera chain.

The term "transfer characteristic" is taken here to define the relation between the illuminance on the television pickup tube and the corresponding luminance of the kinescope. The adjective "dynamic" is used to indicate that the transfer characteristics are measured under actual operating conditions. This paper is concerned only with a film chain consisting of a motion picture film or slide projector, an iconoscope camera, a camera control and a studio monitor.

The calculation of transfer characteristics from published iconoscope and kinescope curves is not a very satisfactory procedure; while the kinescope characteristics are well defined, the iconoscope response cannot be defined by a single curve. Further, the published iconoscope curves are not carried to as high illumination levels as may be used in practice. For example, the *RCA Tube*

Communication No. 1421 from the Kodak Research Laboratories, presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by W. K. Grimwood and T. G. Veal, Kodak Research Laboratory, Rochester 4, N.Y.

Handbook curve of the RCA Type 1850-A Iconoscope ends at 20 ft-c; this is between one-fifth and one-fortieth the illumination that may be used in actual operation. Because of the uncertainty of the iconoscope characteristic, it was felt that measurements might best be made while the television film chain was carrying a picture image. There is not, unfortunately, a single transfer characteristic. Each adjustment of pedestal, gain, shading or kine brightness results in a different characteristic. In general, these controls were set for best picture quality, a criterion which is rather vague and is subject to considerable variation between individuals.

Slide Projection

In order to measure the television transfer characteristic, we have used a method developed by J. G. Streiffert, of the Kodak Research Laboratory. One or more perforations are punched in a slide of any suitable subject. Pieces punched from a film of uniform density are cemented into these perforations. A series of such slides are fabricated, the inserted "densities" being different in each slide. The slides are essentially identical prints from the same negative (except for the inserted densities), and the perforations are punched from a template so that they will be in the same area of the picture in all slides. One slide from a group of twenty-eight is shown in Fig. 1. Each slide in this group has three measuring areas: the spot in the white dress will be called spot W, the one in the black dress, B, and the one in the gray dress, G. The spots are $\frac{1}{8}$ in. in diameter and comprise about 1% of the useful area of the Retina-Camera size slide. While the area of the spots is too small to affect the response of the iconoscope to the picture signals, the

Fig. 1. Sample slide, showing measurement areas.

spots do have a noticeable effect under some conditions. If the spot densities are either higher or lower than the highest and lowest densities, respectively, in the picture, the average luminance of the picture on the kinescope will shift slightly. For the series of slides illustrated by Fig. 1, the highest and lowest densities were approximately 2.6 and 0.3, respectively. Above and below these densities there may be some question as to the accuracy of the data.

The slide projection used for these measurements was a Kodaslide Projector, Model 2A, equipped with an Ektar *f*/4.5 enlarging lens and masked to project the 3 : 4 picture ratio used in television. The television equipment was an RCA film camera chain using a Type 1850-A Iconoscope and an RCA Type 1816P4 Kinescope. Relative illuminances and luminances were measured with a Welsh Densichron. The Densichron modulates the photoelectric current by subjecting the electron stream to a 60-cps magnetic field. When the kinescope luminance is measured, this modulating field is not necessary, since the light is already modulated by the television 60-field scanning, so that a switch was installed in the Densichron to "open-circuit" the modulating field. In order to make the Densichron probe less sensitive to position when the kinescope luminance is measured, the probe was modified so as to accept only a narrow cone of light. The phototube used has an S4 surface.

In general, the measuring procedure consists in adjusting the camera controls until a satisfactory picture is obtained, using for this purpose a slide with no spots. The video level is maintained at 2 v

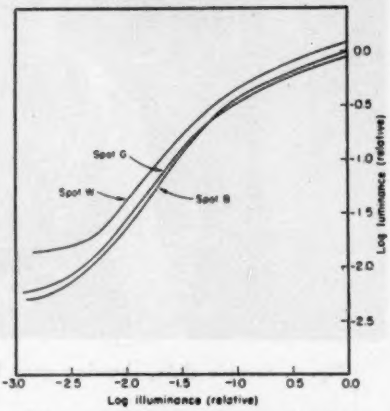


Fig. 2. Slide projection, showing effect of surround.

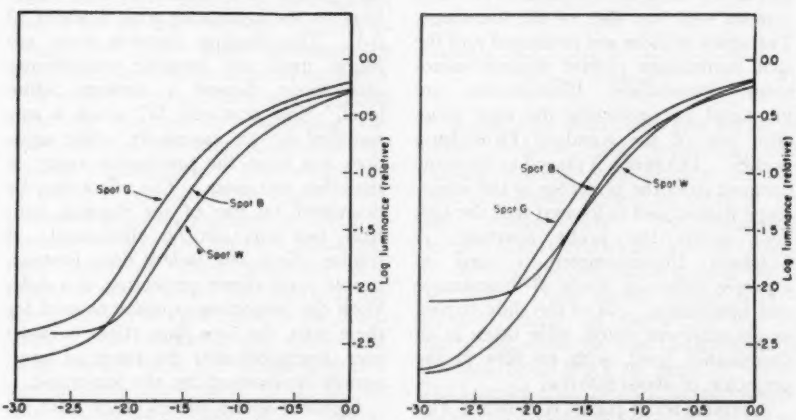


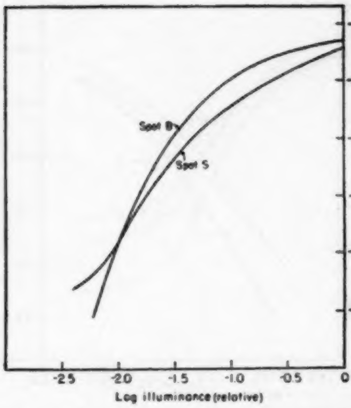
Fig. 3. Transfer characteristic, no shading; left, slide normal; right, slide reversed.

Fig. 4. Sample slide, showing gray background, and measurement areas.

peak-to-peak. Measurements are then made of the kinescope luminance in the spot areas, using the Densichron probe in contact with the face of the kinescope. The series of slides are measured and the spot luminances plotted against iconoscope illuminance. Illuminances are measured by projecting the slide series onto one of the standard Densichron probes. The probe is placed at the same distance from the projector as the iconoscope mosaic and so located that the spot area covers the probe aperture. A Macbeth Illuminometer is used to measure reference levels of illuminance and luminance. All of the slide curves, unless otherwise noted, were taken at an illuminance level, with no film in the projector, of about 800 ft-c.

A typical set of curves is shown in Fig. 2. This figure also illustrates the effect of the luminance of the area surrounding the measuring spot. The controls were set for what was judged to be good picture quality in a darkened room. Zero level on the luminance scale is about 12 ft-L. The shading controls were adjusted until the monitor cathode-ray oscilloscope showed a uniform white level. Note that spot W, which is surrounded by an essentially white area, does not have the luminance range of the other two spots. This effect may be decreased by use of the shading controls, but may not be eliminated. A similar effect, due to lens flare, is measurable upon direct projection of a slide. With the projection equipment used for these tests, the lens flare effect is, however, negligible over the range of luminances reproduced by the kinescope.

Figure 3 shows curves taken with no shading signals. The two sets of data are comparable, the only difference be-



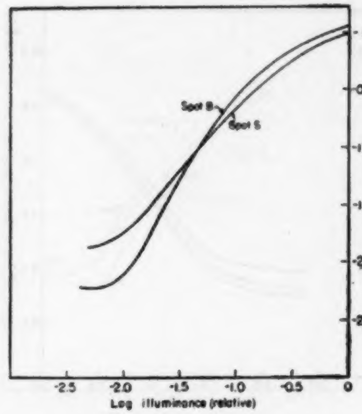
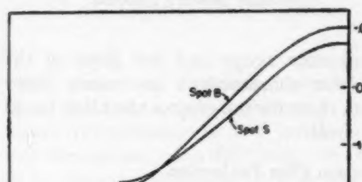


Fig. 5. Slide projection, showing progressive change of curvature and maximum slope of transfer characteristics as background changes from black (above, left) to gray (above, right) to white (right).



tween them being that that on the right was taken with the slides reversed right and left, so that spot W, normally on the left side of the picture, is, in the right part of Fig. 3, on the right side of the picture. Comparison of the two sets of curves shows only small differences between the two B curves and between the two G curves, but fairly large differences in shape and slope between the W curves.

A second series of slides was prepared with the objective of illustrating the effect of the picture background upon the transfer characteristic. These slides, one of which is reproduced in Fig. 4, were prepared from photographs of a girl in evening dress seated before a plain curtain backdrop. Three negatives were taken, in one of which the backdrop was black, in another, gray, and in the third, white. One measuring spot, designated as B, was located in the background area and another, designated as S, in the subject's shoulder. The transfer characteristic was measured on the same equipment and by the same technique as used in conjunction with the first series of slides. Pedestal, gain, brightness, and shading controls were adjusted for the most acceptable picture for each of the three backgrounds. The measured transfer characteristics are shown in Fig. 5. Zero on the luminance scale of Fig. 5 is 6 ft-L. These curves exhibit a progressive change of curvature and of maximum slope as the background is changed from black to gray to white. The transfer characteristic for the white-background pictures has a nearly linear central portion and pronounced highlight and shadow compression. The

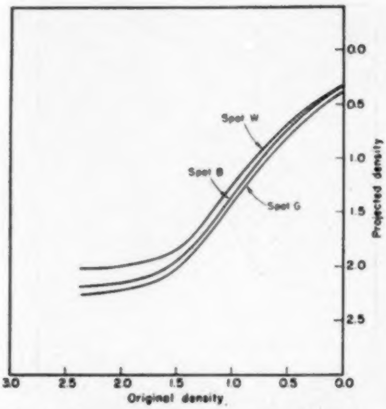


Fig. 6. Transfer characteristic of 16-mm motion picture process.

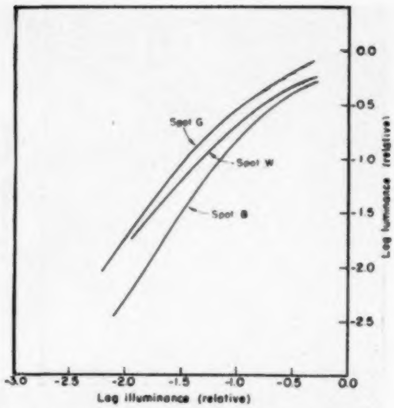


Fig. 7. Television transfer characteristic, 16-mm film projection.

luminance range and the slope of the transfer characteristic are much lower than those for the gray or the black backgrounds.

16-Mm Film Projection

The technique used in measuring the television transfer characteristic for 16-mm film projection is similar to that used for slide projection, except that the measuring areas were produced photographically. A negative of the same scene as was used for the slide measurements was enlarged from a usable size of $2\frac{3}{4}$ by $3\frac{1}{2}$ in. to 11 by 14 in. One-inch holes were punched in this positive transparency in the same locations as were used for the spot areas in the slides. The transparency was laid on an illuminator and photographed with a 16-mm camera, the holes being filled with 1-in. disks of neutral nondiffusing densities. A series of 16-mm photographs were taken, a different value of neutral density being used for each section of the 16-mm film. A contact print of the 16-mm negative was projected onto the iconoscope mosaic by the Eastman Model 250 Projector. With no film in the gate, the illuminance on the mosaic was 260 ft-c. Luminances and illuminances were measured with the Densichron in a manner similar to that described in connection with the slide measurements.

Since the 16-mm films are made by photographing a transparency in which there are inserts of known densities, data are available on the overall motion picture characteristics (including camera and projection optics) as well as on the television characteristic. Figure 6 shows the photographic characteristic and Fig. 7 is one set of curves of the television characteristic. The differences between the curves of Fig. 6 are due to unevennesses in illuminance in the taking and projection processes. These unevennesses do not enter into the curves of Fig. 7; here, the differences are chiefly associated with shading. Note that in this example the television characteristic has a greater range of luminances than the photographic process characteristic. Not all this range is usable, however, because the low luminance levels are normally masked by room lighting. While the characteristic of Fig. 7 may give somewhat poorer picture quality than that of Fig. 6, because of the greater highlight compression, either characteristic should result in acceptable tone rendition. The product of these

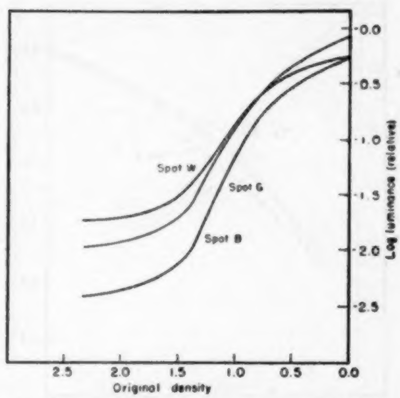


Fig. 8. Overall transfer characteristic. 16-mm motion picture process televised by iconoscope film camera chain.

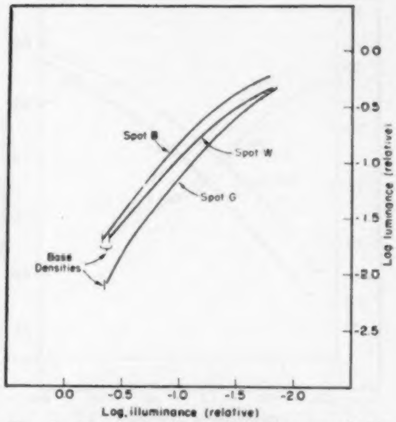


Fig. 9. Television transfer characteristic, 16-mm negative film projection.

two characteristics is, as may be expected from Fig. 8, far from satisfactory. The spread between the three curves of Fig. 8, especially in the shadow region, is not particularly significant, since it may be largely corrected by adjustment of the shading controls. In a television film chain using only linear amplifiers, little can be done to correct the severe highlight compression of the overall transfer characteristic. Readjustment of the operating controls to improve tone rendition in the highlights merely results in poor tone rendition in some other portion of the tone scale.

Figure 6 should not be taken to represent the optimum tone reproduction of the motion picture process. It does, however, illustrate the kind of characteristic which gives good picture quality. That the tone reproduction characteristic of the motion picture process is curved rather than linear, is not due to the technical inability to produce, within reasonable limits, a linear characteristic. The overall tone reproduction curve of the motion picture process is the result of the motion picture industry's years of practical experience. Any assumption that the relation between screen luminance and scene illuminance should be linear for either motion picture or television reproduction is not justified by this experience. If a television screen is to be viewed under conditions similar to the viewing of motion picture screens, the television film chain transfer characteristic should be approximately linear. (Alternatively, the television characteristic could be curved and the film characteristic linear; this would restrict the television pickup to specially made films.) The statement that the television transfer characteristic should be linear contains the implicit assumption that the material to be televised is a motion picture of good direct-projection quality. It is customary, in filming pictures for television use, to use flatter lighting than for pictures taken for distribution in theaters. Satisfactory reproduction of such material requires that the relation between the logarithm of luminance and the logarithm of illuminance be linear, with a slope greater than unity. The apparent high contrast of the television transfer characteristics shown in this paper is, in part, due to the use of original negatives taken with low-contrast lighting.

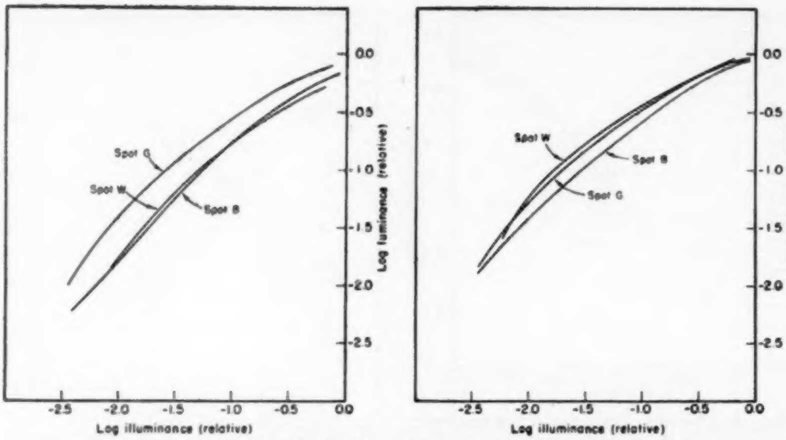


Fig. 10. Television transfer characteristic, 16-mm film projection; left, shading A; right, shading B.

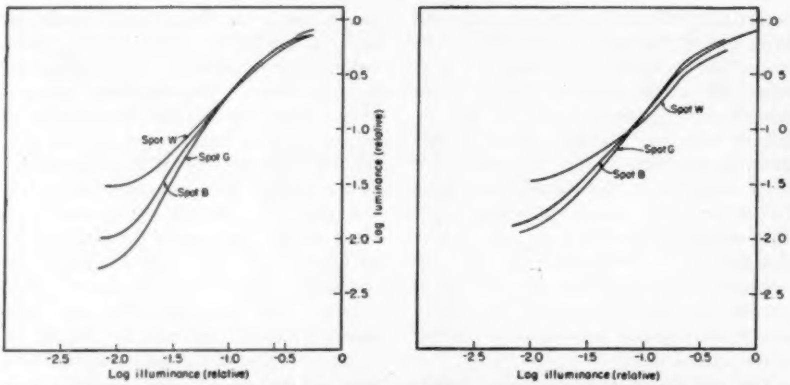
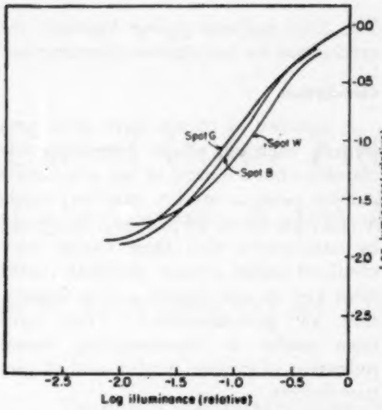


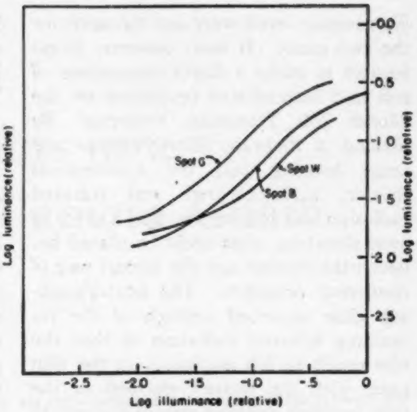
Fig. 11. Television transfer characteristic, 16-mm film projection (filtered light); left, normal illuminance; right, low illuminance.

It is well known that televising a negative over an iconoscope camera results in better picture quality than the televising of a print. While there are several reasons for the improvement, one reason is a more linear transfer characteristic, as may be seen from Fig. 9. Figure 9 is from measurements on the negative from which the print was made for the measurements plotted in Fig. 7.

Adjustment of the shading controls does not merely raise or lower the transfer characteristic relative to the luminance scale. Figure 10 illustrates the sort of change that results from even a slight readjustment of shading. The data of the left part of Fig. 10 were taken under the same conditions as the data of the right part, except for the shading-control setting. Readjustment of shading has left spot G practically unchanged. Spots B and W have been shifted upward



(a) Shutter stationary

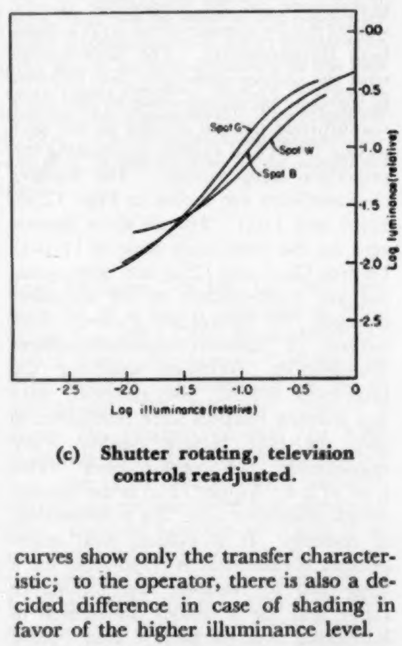


(b) Shutter rotating

Fig. 12. Television transfer characteristic, 16-mm film projection (filtered light).

on the luminance scale, but at the same time their slope has been reduced. It appears to be generally true that the slope of the luminance-versus-illuminance curve is changed by the shading; in regions where shading is used to raise the average brightness, the slope is decreased, and vice versa.

The effect of illuminance level upon the transfer characteristic is illustrated by Fig. 11. Data for both sets of curves were taken with color filters in the projector condenser system. The zero of the illuminance scale for the left set of curves represents a level of 91.5 ft-c. For the right set of curves, zero level represents 91.5 ft-c attenuated by a nondiffusing neutral density of 0.7. Zero on the luminance scale is 5.6 ft-L for both figures. At each illuminance level, the television controls were adjusted to give what was considered to be the most satisfactory picture quality obtainable. The transfer characteristic measured at the lower illuminance level exhibits a shorter range of luminances and more marked highlight compression than the higher-level characteristic. These



(c) Shutter rotating, television controls readjusted.

curves show only the transfer characteristic; to the operator, there is also a decided difference in case of shading in favor of the higher illuminance level.

Still-Versus-Motion Picture Projection

The transfer characteristics shown for still projection and those for motion picture projection cannot be compared directly because the picture sizes and the

illuminance levels were not the same for the two cases. It was, however, found feasible to make a direct comparison of still and intermittent projection on the Model 250 Television Projector. By placing a dichroic filter between the lamp housing and the synchronous shutter, sufficient red and infrared radiation was reflected so that a piece of heat-absorbing glass could be placed between the shutter and the second pair of condenser elements. The heat-absorbing glass absorbed enough of the remaining infrared radiation so that the film could be left stationary in the film gate, with the shutter stopped in the open position, without serious damage to the film. With the shutter rotating, the illuminance on the iconoscope mosaic was 92 ft-c by measurement with a Macbeth Illuminometer. The illuminance, with the shutter stationary, was reduced to the same measured value by placing a nondiffusing neutral density in the projection beam and slightly readjusting the projection lamp voltage. The transfer characteristics are shown in Figs. 12(a), 12(b) and 12(c). For all three figures, zero on the luminance scale is 11 ft-L. Figures 12(a) and 12(b) are taken without any readjustment of the television controls; the figures are a direct comparison of constant-versus-intermittent illumination. Without touching the brightness control, the pedestal, gain and shading controls were readjusted to give the best picture quality while maintaining the peak-to-peak video level at 2 v. Figure 12(c) is the characteristic measured after this readjustment of controls. It is evident that intermittent illumination is responsible for a large loss in contrast and luminance range and for a serious unevenness of luminance over the picture area. Most of this loss, but not all, is regained by adjustment of the controls. Although the curves for still and for intermittent projection (after adjustment of the controls) are similar in shape, the curves of Fig. 12(c) indicate poorer highlight reproduction for intermittent illumination.

Conclusion

A number of curves have been presented, each of which represents the transfer characteristic of an iconoscope camera and a studio monitor under actual operating conditions. It should be emphasized that these curves were obtained under certain specified conditions and do not furnish a firm foundation for generalizations. They have been useful in corroborating visual judgment of picture quality and of picture defects.

There is no single transfer characteristic representing the light input–light output relation in an iconoscope film chain nor can a single specification exist, so long as the transfer characteristic is a function of the distribution of the light transmitted by the subject material.

Discussion

C. R. Keith: What density steps are used in these tests?

Mr. Veal: We used 0.1 density steps in the range of 0 to 2.5.

R. O. Drew: As photographic people like to think of gamma, even in terms of television equipment, what was the overall gamma of the iconoscope, kinescope and film characteristic that you used in taking these pictures?

Mr. Grimwood: With one exception the curves do not include the film characteristic. Most of the curves have no linear portion so there is no gamma in the photographic sense. The maximum slope in the mid-portion of these curves is likely to be higher than that of a curve having a long linear region. This is a compromise which must be made to obtain some semblance of tone scale in the end portions of the curves. In addition, the slope of the transfer characteristic is partly a compensation for the low-contrast lighting that is frequently used in producing film for televising.

Use of Color Filters in a Television Film Camera Chain

By W. K. GRIMWOOD and T. G. VEAL

The quality of pictures televised by an iconoscope film camera is improved by removing the red and infrared portions of the radiation incident upon the mosaic of the iconoscope. The combination of heat-absorbing glass with either an absorption or a reflection type of color filter can be used in the condenser optical system of a 16-mm projector. Such a combination of filters reduces the heat at the film gate enough to permit the film to be held stationary in the gate without damage to the film. The color filters improve picture sharpness, reduce shading requirements, and increase the signal level. The improvement in sharpness is partly an optical effect. The increase in signal level, despite the reduction of photoactive radiation, is believed to be an electronic effect peculiar to the iconoscope principle.

It has been found that the quality of pictures produced by a television film chain is improved if the red and infrared components are removed from the radiation incident upon the mosaic of the iconoscope. Experimental work with a number of color filters, of which the three curves of Fig. 1 are illustrative, was carried out on the Eastman 16-Mm Television Projector, Model 250. The light source of this projector is a tungsten lamp operated at about 3400 K. The greatest improvement in picture quality was observed when using the filter defined by curve 2 in Fig. 1. This combination of a 6-mm thickness of Pittsburgh No. 2043 Glass (heat-absorbing) and a 3-mm thickness of Corning No. 9780 Filter is recommended for use in the Model 250 Projector. Figure 2 shows the location of the two filter glasses between the synchronous shutter and the film plane. This location necessitates the use of the heat-absorbing glass, the sole function of which is to reduce the infrared energy in the projection beam so that there is no danger of breakage of the Corning filter from heat absorption. Placing the filters between the shutter and the film is preferable to inserting the filters between the projection lens and the iconoscope, for several reasons. The latter choice is undesirable because it injects the possibility of image degradation due to optical imper-

Communication No. 1409 from the Kodak Research Laboratories, a paper presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by W. K. Grimwood and T. G. Veal, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y.

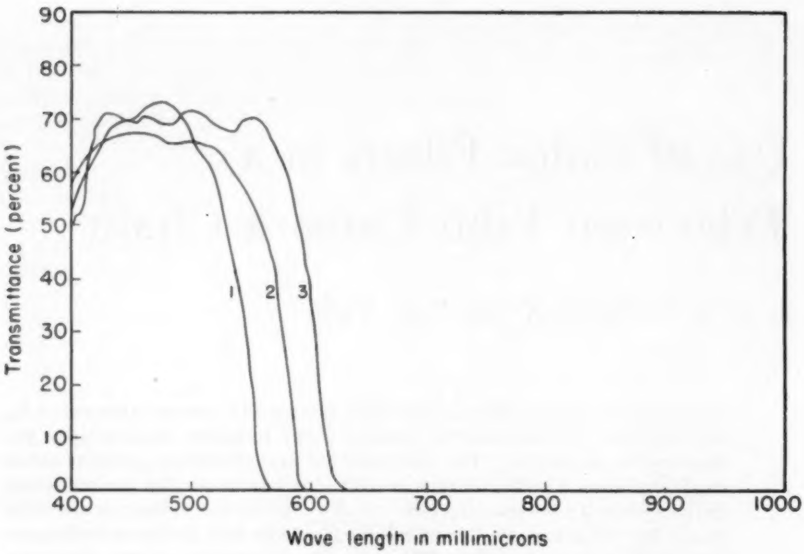


Fig. 1. Spectrophotometric curves of filters used in 16-mm television projector: Curve 1, dichroic No. 1 plus Pittsburgh No. 2043, 4 mm thick; curve 2, Corning No. 9780, 3 mm thick plus Pittsburgh No. 2043, 6 mm thick; curve 3, dichroic No. 2 plus Pittsburgh No. 2043, 4 mm thick.

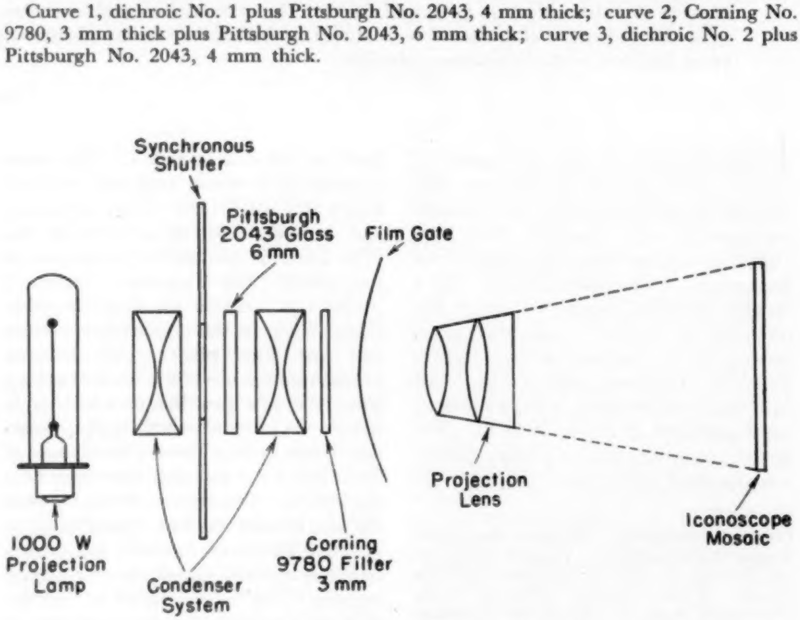


Fig. 2. Eastman Model 250 Projector optical system.

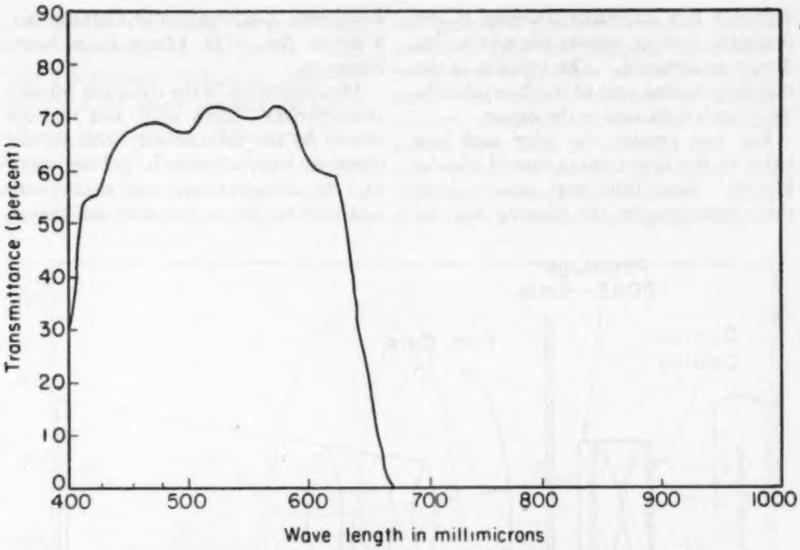


Fig. 3. Spectrophotometric curve of filters used in 16-mm projector of 100 ft-c illuminance. Dichroic filter plus Pittsburgh No. 2043, 4 mm thick.

fections in the filter glass, or to accumulation of dust on the filter surfaces. The filter itself is more exposed to accidental breakage. The most compelling reason, however, is that when the filters are located in the condenser system, the film can be left stationary in the film gate (with the shutter operating) for an indefinite period without buckling. The radiant flux at the film gate is 0.55 mw/sq cm, one seventeenth of the unfiltered value. The filters absorb about 35% of the energy within their passband and have a transmittance of 10% at 590 mμ.

With a projector illuminance of 250 ft-c, the loss of photoactive light by filter absorption is not serious, but with a projector illuminance of the order of 100 ft-c, this absorption becomes a more important factor. Furthermore, glass filters occupy appreciable space which may not be available in a projector condenser system. In such situations, the dichroic or interference type of filter is therefore useful. The dichroic filter not only has low loss in the transmitted band, but removes unwanted radiation by reflection rather than by absorption. The latter property makes it possible to coat the dichroic filter directly on the rear element of the condenser optics. A disadvantage of the dichroic filter is its band-elimination type of characteristic, that is, the transmittance drops to a level of perhaps one quarter to one half of 1% in the red, but at still longer wavelengths the transmittance increases rapidly. Fortunately, Pittsburgh No. 2043 Glass has sufficient absorption in the region where the dichroic filter fails, so that the combination of this glass and the dichroic filter results in a satisfactory filter. Figure 3 shows the absorption curve of a dichroic filter plus a 4-mm thickness of the heat-absorbing glass (Pittsburgh No. 2043). For this combination, the 10% transmittance point is at 640 mμ; thus, there is less loss of photoactive light with this filter than with that described by curve 2 of Fig. 1.

Figure 4 is a schematic drawing of the projector optical system for which this filter was designed. The location of the dichroic coating and of the heat-absorbing glass is indicated in the figure.

For best results, the edge and bias lights in the film camera should also be filtered. Since little heat radiates from these light sources, the filtering may be done with 2-in. squares of Corning No. 9780 or No. 9788 Filters in a 3-mm thickness.

Measurements of the dynamic transfer characteristic, taken with and without filters, do not satisfactorily indicate the observed improvement in picture quality. If measurements are made with and without filters, but with no change

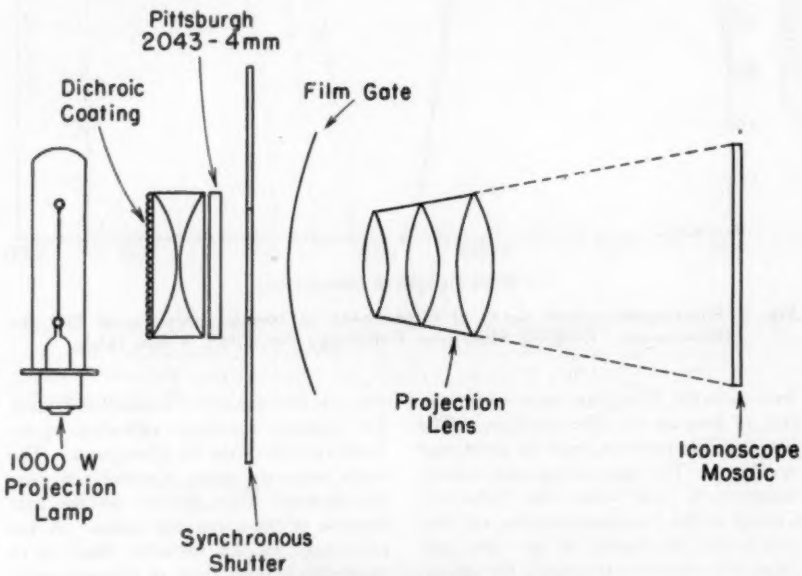


Fig. 4. Projector optical system.

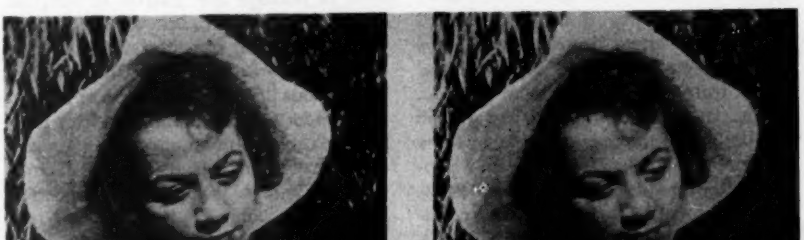


Fig. 5. Photographs of the monitor kinescope images. Photographs from the same frame of a normal 16-mm print. Left, with filters; right, without filters.

in the television controls, there will be a distinct difference in the curves. This is not a legitimate technique, since the insertion of the filters changes the signal level and the shading. The signal level increases and the contrast increases, but these changes may also be produced in the unfiltered picture by manipulation of the gain and pedestal controls. When pedestal, gain and shading have been readjusted to produce an unfiltered picture which visually matches the filtered picture, then the transfer characteristic curves have been so modified that it is not possible to ascribe specifically any difference in shape to the filters. Small differences in the critical highlight region

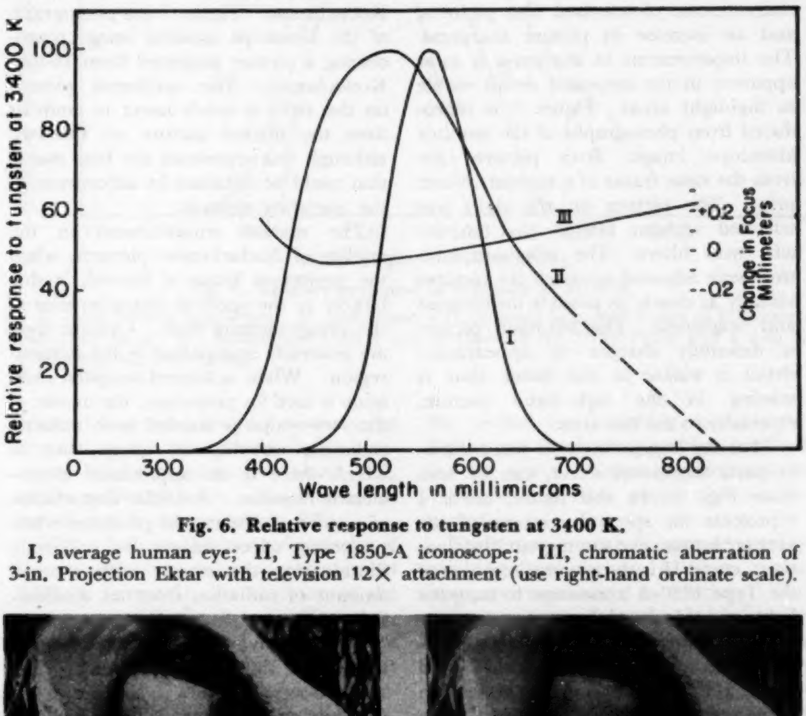


Fig. 6. Relative response to tungsten at 3400 K.

I, average human eye; II, Type 1850-A iconoscope; III, chromatic aberration of 3-in. Projection Ektar with television 12× attachment (use right-hand ordinate scale).

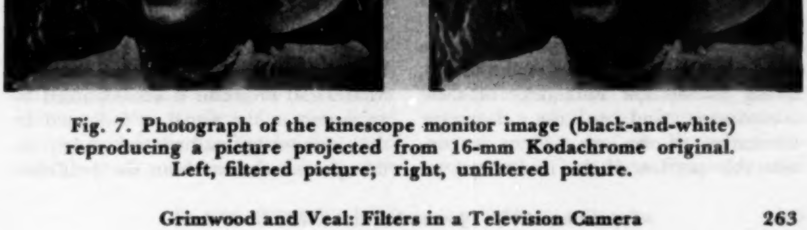


Fig. 7. Photograph of the kinescope monitor image (black-and-white) reproducing a picture projected from 16-mm Kodachrome original. Left, filtered picture; right, unfiltered picture.

are especially likely to be masked by shading-control adjustments.

Although the effects of color filters are not obvious from transfer characteristic measurements, the effects are readily perceived upon visual examination. With filters installed in the projector and in the television film camera, the most noticeable change in the picture is a reduction of the haze or veil which is characteristic of televised film pictures, and an increase in picture sharpness. The improvement in sharpness is most apparent in the increased detail visible in highlight areas. Figure 5 is reproduced from photographs of the monitor kinescope image. Both pictures are from the same frame of a normal 16-mm print. The picture on the right was televised without filters; that on the left, with filters. The television controls were adjusted to match the pictures visually as closely as possible for contrast and brightness. The left-hand picture is definitely sharper in appearance; detail is visible in the latter that is missing in the right-hand picture, especially in the hat area.

That the improvement in sharpness is, in part, an optical effect, can be seen from Fig. 6. In this figure, curve I represents the spectral response of the average human eye to tungsten illumination; curve II is the spectral response of the Type 1850-A iconoscope to tungsten light, as calculated from the response curve published in the *RCA Tube Handbook* (extrapolated to 800 mμ); and curve III is the chromatic aberration curve of the projection lens used in the Eastman Model 250 Projector. Visually, this is an excellent projection lens; no discernible shift in visual focus results from the insertion of the television filters (Fig. 1). The eye, however, is relatively uncritical of the sharpness of the red and blue components of the image, owing to the low luminosity of these components and to the chromatic aberration of the eye. Since a considerable portion of the iconoscope response lies in the red and infrared regions, where the focal plane of the lens does not coincide with that of the green, it is reasonable to expect the sharpness of televised pictures to be improved by the removal of this red and infrared radiation.

The most striking improvement in picture quality is found in the televising, in black-and-white, of color film such as Kodachrome. Figure 7 is a photograph of the kinescope monitor image reproducing a picture projected from 16-mm Kodachrome. The unfiltered picture on the right is much lower in contrast than the filtered picture on the left, although this represents the best match that could be obtained by adjustment of the operating controls.

The marked improvement in the quality of Kodachrome pictures, when the projection beam is filtered, is due largely to the spectral characteristics of the image-forming dyes. Organic dyes are generally transparent in the infrared region. When unfiltered tungsten radiation is used for projection, the mosaic of the iconoscope is flooded with infrared radiation carrying no image, but to which there is an appreciable photoelectric response. A similar degradation of picture quality can be produced when projecting silver images by uniformly illuminating the mosaic with a small amount of radiation from an auxiliary light source.

A major advantage in using filters is a decrease in shading requirements. The scene-to-scene changes in shading, when projecting motion pictures, are reduced to such an extent that shading readjustments are necessary only when there are radical changes in the distribution of light and dark areas in the picture.

The improvement in shading appears to be associated with an increase in signal level. The insertion of filters in the Model 250 Projector is accompanied by an *increase* in the signal as indicated by the monitoring cathode-ray tube, although calculations from the published

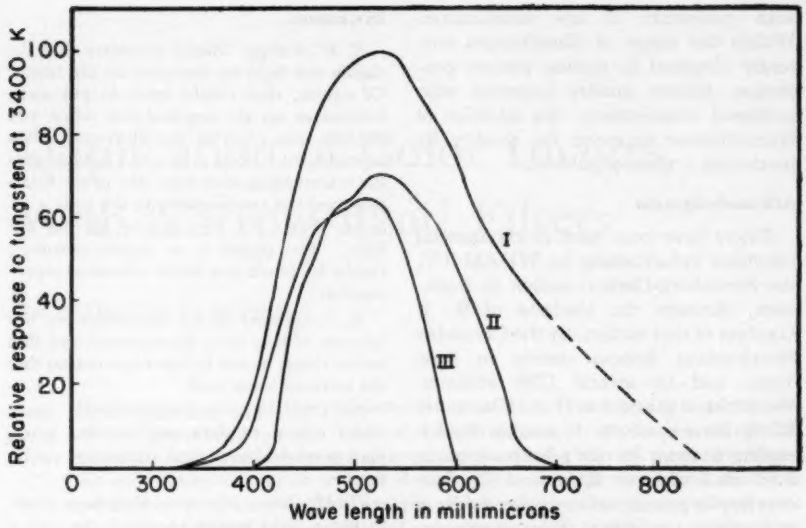


Fig. 8. Relative response to tungsten at 3400 K.

I, Type 1580-A iconoscope; II, iconoscope with dichroic filter and 4 mm of Pittsburgh No. 2043 Glass; III, iconoscope with 3 mm of Corning No. 9780 Filter and 6 mm of Pittsburgh No. 2043 Glass.

spectral-response curve of the iconoscope show that the photoactive light is reduced by the filters to only about 40% of the unfiltered value. The increase in signal level is approximately 20%.

Figure 8 shows the spectral response of the iconoscope to tungsten radiation at 3400 K (curve I), the response of the iconoscope with the dichroic filter combination (curve II), and the response of the iconoscope with the glass filters (curve III). Although the total photoactive radiation is reduced by filtering, as shown by the relative areas of these three curves, the average velocity of primary electron emission from the mosaic is increased, since the velocity of emission is greater for the shorter wavelengths. Higher average velocity should increase the distance between the space charge and the mosaic, so that fewer electrons are repelled by the space charge and fewer are lost by the space charge to the mosaic. It follows that the output level could reasonably be higher and the shading problem lessened by this action. Some improvement in highlight resolution could also be expected.

The improvement in picture quality resulting from the use of filters varies from one iconoscope to another. The differences in results are probably largely due to variations in the response to red and infrared, relative to the response to blue among iconoscopes. The edge-light filter which usually reduces edge flare has little effect with some iconoscopes, and has little or no effect when low-illuminance edge lighting is used. The bias-light filter normally results in a less critical bias-light adjustment for application-bar cancellation, but frequently has no appreciable effect. Filtering the projection beam nearly always results in a worth-while improvement in picture quality, but the degree of improvement is less when filters are used

with projectors of low illuminance. Within the range of illuminances currently obtained in motion picture projection, picture quality improves with increased illumination; the addition of filters further improves the quality by producing a sharper picture.

Acknowledgment

Filters have been used in commercial television broadcasting by WHAM-TV, the Stromberg-Carlson station in Rochester, through the kindness of K. J. Gardner of that station, by the Columbia Broadcasting System station in New York, and by several CBS affiliates. We are most grateful to H. A. Chinn and K. B. Benson, of the Columbia Broadcasting System, for their cooperation in field trials of these filters and for their courtesy in passing on to us the results of their field experience from numerous filter installations.

We wish also to acknowledge the contributions of George Koch, Development Dept., Camera Works, Eastman Kodak Co., who made the dichroic filters used in their experiments, and those of numerous members of the Research Laboratory staff.

Discussion

E. W. Kellogg: Was it necessary that the visible red light be removed by the filters? Of course, that would seem to put some limitations on the applicability when you get into color, but as you illustrated when reproducing a color original, I noticed that the transmission characteristics of the filters you used cut considerably in the red.

Mr. Veal: We do remove all the red light. The object is to obtain optimum results for black-and-white television reproduction.

R. L. Garman: Is the ultraviolet cut out because of lens flare, fluorescence and that sort of thing, or is it for the same reason that the infrared is cut out?

Mr. Veal: The reduction of the ultraviolet was not deliberate, but the filters used removed part of the ultraviolet radiation.

H. M. Gurin: Has any effort been made to use a light source in which the red is absent, so that the use of filters could be avoided?

Mr. Veal: The GE pulsed light source is widely used. With the new FT231 lamp it is unlikely that there would be much improvement when reproducing a black-and-white picture. The use of filters would be advisable when reproducing a color picture in black-and-white.

Duplication of Color Images With Narrow-Band Filters

By RODGER J. ROSS

Outlined are some of the problems of the users of direct-positive subtractive color films, such as Ansco Color and Kodachrome, in producing acceptable duplicate images which in some cases may be third-generation reproductions. An experimental project will be described in which it was found that it is possible to produce duplicate images which may be directly compared with the camera originals by exposing the duplicating film with filters transmitting three relatively narrow spectral bands. While no attempt has been made in this paper to deal in any detail with the theoretical aspects of color reproduction, a number of factors which are of great concern to the users of color materials have been noted — particularly the establishment of visual acceptance limits for color images, and the influence of processing upon the shape and relationship of the three-color density curves representing an image of a neutral wedge.

In the normal white-light printing of color film, deliberate alteration of the color balance may be employed to produce duplicate images which are quite satisfactory for some purposes. In the hands of a skillful technician, the results which can be achieved in this way are quite surprising. For instance, large numbers of excellent 16-mm motion picture prints have been produced by direct printing from the camera originals.[1,2]

The problems involved in the reproduction of larger still transparencies are considerably more severe. Here it is possible for the observer to relate the appearance of individual colors in an image to objects in the immediate vicinity, or to make side-by-side comparison of images. In addition, there is ample opportunity for leisurely evaluation of different image areas.

The appearance of a color image is often described by the term "color balance." This term is at best an uncertain indication of the characteristics of a color image, for it is well known that color balance may be influenced by such factors as the conditions of viewing. Visual evaluation, while suggesting the direction in which correction should be made, provides no indication of the degree of correction required, or the

Presented on April 30, 1951, at the Society's Convention at New York, by Rodger J. Ross, Special Effects Div., National Film Board of Canada, John Street, Ottawa, Ontario, Canada.

nature and extent of the factors which are responsible for unsatisfactory appearance.

In any attempt to improve the quality or appearance of color images, it is very difficult to demonstrate conclusively the degree of improvement that is obtained in a particular case. The best that can be done is to say that, as a result of visual evaluation, the image is a pleasing representation of the original object or scene, or that a duplicate image closely resembles the original image from which it was made. This might be defined as a process of establishing acceptance limits within which satisfactory images may be obtained. Since the eye is particularly sensitive to differences in colors in side-by-side comparisons, the acceptance limits established in direct comparison of duplicate and original color images might be expected to be severely restricted, as opposed to a condition under which an image is evaluated in respect to its pleasing appearance.

The Color Sensitometry Subcommittee of this Society, in a report published in the JOURNAL,[3] describes the progress that has been made in extending black-and-white sensitometric procedures to the evaluation of color materials and color images. One of the requirements of a color process might be said to be the reproduction of a neutral gray scale or wedge as a neutral image. The image of a neutral wedge might be represented by three curves on graph paper, derived from color density measurements on the image. Any system of this kind, however, must take into account the differences in the effects of a color image upon the eye and its influence upon another color material when duplicates must be made. There is the problem, too, of representing just-visible differences between color images of objects or scenes by significant quantitative differences in measurements upon a wedge image. Furthermore, a neutral image of a wedge is by no means an absolute requirement of a visually satisfactory image of a colored object. It should be possible eventually, however, to describe a color image in terms of a series of numbers, or as patterns upon a chart or graph paper, and to apply this information in the control of exposure and processing of color materials, in order to ensure that an image will be obtained within the acceptance limits established as a result of visual evaluation.

The deficiencies of the dyes of subtractive color materials have been described in detail in the literature. In brief, it may be said that as the result of the unsatisfactory transmissions and absorptions of available dyes, the colors in duplicate images will become degraded or desaturated.[4] In addition, the contrast of a color image must be relatively high to obtain satisfactory color saturation.[5,6] When a color image such as this must be reproduced on another color material with similar contrast characteristics, the contrast of the duplicate image will be further increased. Masking has been recommended as at least a partial solution for these problems. While it has been shown that it is possible to overcome completely the deficiencies of the subtractive process by masking, this would require the use of multiple masks. It is seldom practical, however, to utilize more than one mask in duplication. The practical difficulties involved in making and registering even a single mask have limited the use of masking procedures, particularly in motion picture printing.

Requirements for Two Languages

A basic problem of the National Film Board of Canada is the production of 16-mm color films in English- and French-language versions — one of which must be printed from color masters. When the Technical Research Division first undertook a study of the problems of color reproduction in the autumn of 1947, it appeared that no worth-while

contribution could be made by further work on conventional color-correction methods. The possibilities were considered, however, of reproducing color film with three narrow spectral bands instead of white light. The idea of printing color film in this way was not a new one, even at that time. The Schinzels had proposed in 1937 that positive color prints might be made in this way from Agfa color negatives.[7] Dufaycolor, an additive process, was being printed with three filters.[8] Since then, however, interest in three-filter exposure techniques, especially in motion picture printing, has increased. Eastman Kodak has recommended recently that positive color prints from their new color negative should be produced in this way. Kendall was one of the first to propose that direct-positive subtractive color film might be printed with three filters instead of white light, and described a modified 16-mm step printer which could be used for this purpose.[9] No attempt had been made before this project was initiated, however, to determine the most suitable spectral bands or the degree of improvement which might be obtained with this method of exposure.

The results of the experimental work on this project over the past three years would indicate that this method of reproducing direct-positive subtractive color images has some important advantages. The reproduction of individual colors can be improved and it is possible to exercise considerable control over image contrast. It is very difficult, as previously noted, to specify the exact degree of improvement that may be obtained. Since dye deficiencies are merely reduced and not entirely eliminated by this method of reproduction, duplicate images, identical with the camera originals, cannot be obtained. However, demonstration material has been assembled to indicate that duplicate images representing average objects or scenes may be made to fall within the most critical acceptance limits referred to previously — and it is often difficult to select the camera original. In comparisons of this kind, image contrast is an important factor. Although it may not always be necessary or desirable to do so, the contrast of duplicate images may be reduced by variation of processing until it is actually lower than that of the original, with no adverse effects upon the acceptance limits.

The eye is influenced by color images in such a way that color arrangement is an important factor in obtaining satisfactory duplicate images. In the course of this project it was found that if the original image contains a significant red area, for instance, there may be some degradation or alteration of this area in the duplicate image, and the failure of the process to reproduce this color is immediately apparent. The same degree of degradation or alteration will be present, of course, in all duplicate images produced in the same way, but may not influence the acceptance limits. In determining the most favorable color balance, a number of camera originals with widely different color arrangements should be selected, and with this method of reproduction a balance may be found which is satisfactory for all average scenes, eliminating the necessity for scene-to-scene correction. Further alteration of color balance will not as a rule improve the appearance of duplicates which do not fall within the acceptance limits.

The filters which have been used in the experimental work transmit relatively narrow spectral bands (Fig. 1). The object of this exposure method is to produce an image with each filter which is confined to a single layer of the duplicating film. Therefore, the transmission bands of the filters must be selected and the widths of the bands must be restricted so that this objective may be achieved.

When a color image has been produced by exposure in a camera, it should no longer be necessary to consider this

image in the same sense as an original scene for the purposes of further reproduction, but rather as a set of three dye images into which the scene has been separated. The object in duplication, then, is to transfer each individual dye image to the corresponding layer in the duplicating film. Because of the undesirable transmitting and absorbing characteristics of the color-film dyes, there must always be more or less dye in the various areas in the corresponding layers of the duplicating film than in the three layers of the original image.

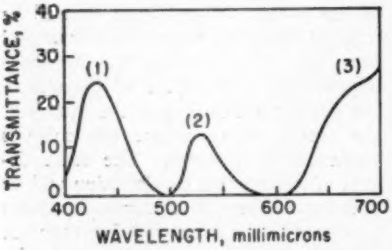


Fig. 1. The filters that have been used in the experimental work on the color duplication project.

When exposure is made with suitable filters, the light transmitted by the three superimposed dye images of the original film will be modified to that which will pass through these filters (Fig. 2).

The transmission of the magenta dye in a color film for red, green and blue is not sharply defined, but passes gradually from one color to another. For a given sensitivity band of the green-sensitive layer of a duplicating film, then, the effective green transmission of the magenta layer may be much greater than it might appear to be. It would seem to be obvious that, since the starting point in color degradation and distortion is to be found in this unwanted green transmission, considerable improvement should be obtained by restricting the transmission of the magenta dye in the green region by means of a narrow-band filter.

The possibility of lowering the contrast of duplicate images by alteration of the processing times was also explored. It was found that the processing times for Ansco Color film exposed with three filters could be reduced by as much as

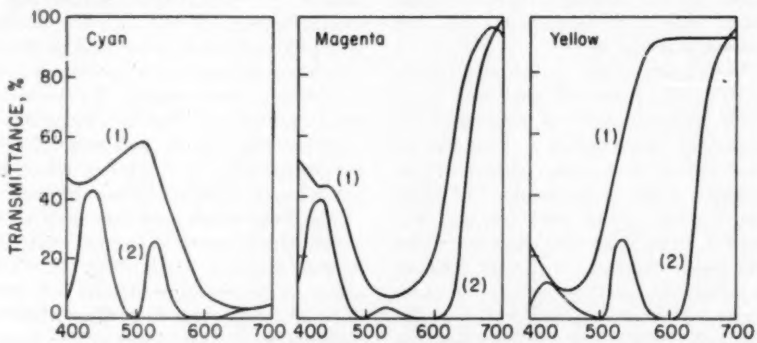


Fig. 2. Spectrophotometric curves.

Curves indicated by (1) were supplied, in each case, by the Kodak Company as representative of the Kodachrome dyes. The curves indicated by (2) were calculated ($\times$4)from data supplied by Kodak on the dyes and the filters selected for the three-filter process. The transmission of the cyan dye in the red, the magenta dye in the green, and the yellow dye in the blue is, of course, undesirable, and if this could be eliminated it should be possible to produce identical duplicate images.

30% from the recommended times, with no apparent adverse effects on the appearance of the duplicate images. Under these conditions, the contrast of the duplicates was somewhat lower than that of the original camera images. However, in lowering the contrast of duplicate images it is very important that the higher densities should be very nearly visually neutral — otherwise undesirable alterations in the appearance of the images will be introduced.

While it was not possible in this project to study in detail the influence of variations in processing times upon the color images, it is known that processing is a significant factor in determining the shape and relationship of the three-color density curves representing an image of a neutral wedge (Fig. 3). This aspect of color-image formation has received little attention in the literature, although the effects of variations in time of first development have been described in some detail by Morse.[10]

In addition, the precise control of color processing is not a simple matter.[11] Slight variations in the constitution of the color developer will exert a strong influence upon color images, and the influence of a particular processing condition may not be the same with different color materials.[12] When a small quantity of color developer is used to process exposed film, changes in the developer between two successive tests may be responsible for a change in the appearance of the duplicate images equal to a variation of 10% in the exposure for one of the filters.

There are, of course, some practical difficulties in applying the three-filter exposure technique in the reproduction of color images. When the exposure system consists of a white-light source with a particular spectral distribution, the illumination or the exposure time may be adjusted so that images will be obtained at a level suitable for viewing or projection, and the spectral distribution of the source may be altered to obtain the desired color balance by means of voltage changes or color-compensating filters. With a three-filter exposure

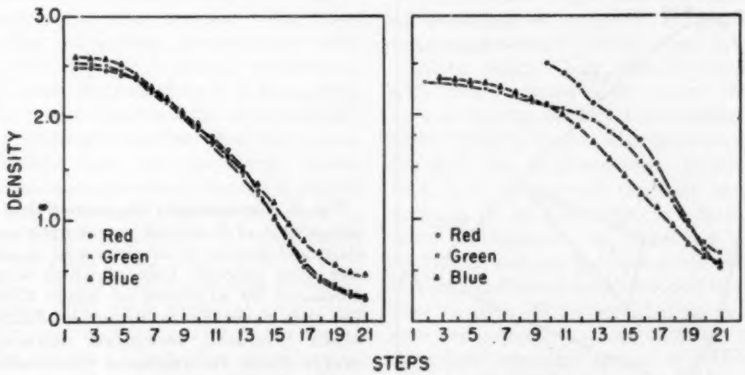


Fig. 3. Color density curves on Ansco Color film.

Left, under controlled processing conditions with which satisfactory demonstration material was produced, i.e., originals and duplicates which could be compared side by side;

Right, conditions representative of commercial motion picture processing, with which it would be impossible to produce duplicate images falling within the acceptance limits of side-by-side comparison.

system in which the light transmitted by each filter presumably affects only a single layer of the film, a different set of conditions must be fulfilled. While it is somewhat more difficult to establish the desired color balance and image level with an exposure system of this kind, it is much more flexible. For instance, tungsten or daylight-type color films may be exposed with the same system by suitably adjusting the ratio of the three-filter exposures. For the most critical purposes, this is a precise procedure compared to the use of color-compensating filters.

The method of exposure also presents some problems. In the reproduction of still images, successive exposures with the three filters may be made. Kendall has described a 16-mm motion picture printer[9] employing an integrating prism and a three-filter exposure system in which narrow-band filters could be used. A single light source could be employed with some means for alternating the filters in the light beam. A number of methods might be used to alter the time or intensity of exposure through each filter to vary the color balance. It should also be possible to employ monochromatic illumination in which case the desired spectral lines or bands might be selected by filters or slits.

The three-filter exposure system has been used to produce duplicates of large still color images that are satisfactory for viewing or further reproduction. A somewhat unusual and successful application for this exposure method was found in the production of 35-mm color-film strips from 16-mm motion picture frames. These "cine-strips" are made in an optical apparatus in which provision is made for exposure through three filters. The color master obtained in this way was printed in a step printer, the lamphouse of which had been modified to expose the third-generation duplicates in the same manner. The three-filter exposure system has also been used successfully by the Banting and Best Institute, University of Toronto, to reproduce medical photomicrographs and color transparencies in which any

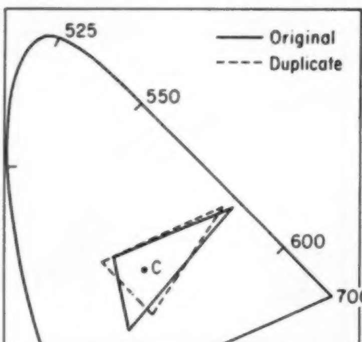


Fig. 4. Chromaticity diagram giving a comparison of dominant wavelength and excitation purity of original and duplicate color patches, both of which were produced by exposure of Ansco Color film with three filters, under conditions which produced acceptable duplicate images (from International Commission on Illumination).

	Yellow		Magenta		Cyan	
	Orig.	Dup.	Orig.	Dup.	Orig.	Dup.
Dominant wavelength	581.9	581.5	559.6C	540.0C	495.5	493.0
Excitation purity	91.00%	87.00%	49.7%	44.0%	23.9%	33.2%
Relative brightness	36.67%	31.32%	4.817%	3.967%	28.65%	16.02%

alteration in color or contrast is particularly undesirable.

The three-filter exposure method is not limited to the reproduction of stills, as has been demonstrated in the continuous printing of film strips in a motion picture printer. The techniques of white-light release printing of motion picture color film, however, have been developed to the point where fairly satisfactory prints may be produced from good-quality camera originals. Any new technique which presents new problems might not prove to be technically or economically practical, in spite of the possibility of further improvements in color quality and contrast. When adequate means have been devised to control printing and processing operations by means of color sensitometric procedures, precise printing methods such as the three-filter exposure technique should prove to be of great value in improving the quality of color release prints.

There is one application in motion picture printing in which the three-filter exposure technique should prove to be particularly useful, however. The intercutting of optical intermediates with camera originals is seldom satisfactory, and such alternatives as A & B printing, and special apparatus for obtaining simple optical effects direct from the camera originals must be employed. Intermediates suitable for intercutting should match the camera originals as closely as possible in color balance, the appearance of individual colors, image level and contrast. It has been shown that duplicate images with these desirable characteristics can be produced with the three-filter process. The problems involved in establishing and maintaining processing conditions, in order that motion picture intermediates with these characteristics may be produced consistently, are such that the closest collaboration with the processing laboratory is required. Facilities for processing lengths of film suitable for screening were not available for this project, and while considerable experimental work has been directed toward the production of optical intermediates, the demonstration material is limited to still images.

Some attention was directed, in the course of this project, to the quantitative evaluation of changes in color balance due to variations in the three-filter exposures, but a satisfactory method for indicating just-visible differences in the appearance of duplicate images has not been found (Fig. 4). The nature and extent of correction, in terms of percentage variation of the filter exposures required to obtain the desired results, was estimated by visual evaluation of comparison images. This is unquestionably a very tedious and uncertain method, and much experimental work is involved in obtaining the best possible results. From the standpoint of the users of subtractive color films, it would be desirable to find some means of establishing acceptance limits for color images, and of interpreting these limits in terms of the nature and extent of the variations in exposure and in the processing conditions which might be required to produce images consistently within these limits.

When Ansco Color film is exposed with three narrow-band filters, there appears to be increased sensitivity to slight changes in the characteristics of the film and in processing. If this is true, this method of exposure might prove to be an advantage, in a form of color sensitometry, in detecting and evaluating film and processing variations of little significance under normal conditions of use. There would seem to be some advantage, too, in utilizing the three-filter exposure system to set up reproducible color exposure conditions which could be readily specified and which should require little maintenance. While variations in the spectral distribution of a light source, now commonly expressed in terms of color temperature, will influence the film whether exposure is made with white light or with narrow-

band filters, it should be possible to specify more precisely the characteristics of an exposure system in relation to the energy in these three bands of the spectrum.

References

1. W. H. Offenhauser, Jr., "Duplication of integral tripac color films," *Jour. SMPE*, vol. 45, pp. 113–134, Aug. 1945.
2. P. S. Aex, "A photoelectric method for determining color balance of 16-mm Kodachrome duplicating printers," *Jour. SMPE*, vol. 49, pp. 425–430, Nov. 1947.
3. Report of the Color Sensitometry Subcommittee, "Principles of color sensitometry," *Jour. SMPTE*, vol. 54, pp. 653–724, June 1950.
4. T. H. Miller, "Masking: a technique for improving the quality of color reproduction," *Jour. SMPE*, vol. 52, pp. 133–155, Feb. 1949.
5. R. H. Bingham, "Sensitometric evaluation of reversible color film," *Jour. SMPE*, vol. 46, pp. 368–378, May 1946.
6. W. T. Hanson, Jr., and F. A. Richey, "Three-color subtractive photography," *Jour. SMPE*, vol. 52, pp. 119–132, Feb. 1949.
7. Karl Schinzel and Ludwig Schinzel, "Copies from Monopack Negatives," *Das Lichtbild*, vol. 12, p. 137, 1937. (Translated by Joseph S. Friedman, *Amer. Photography*, vol. 32, p. 439, June 1938.)
8. A. B. Klein, "Color cinematography," Chapman & Hall, London, 1939, p. 438.
9. O. K. Kendall, "16-mm film color compensation," *Jour. SMPTE*, vol. 54, pp. 464–479, Apr. 1950.
10. H. G. Morse, "Color film exposure and first development timing," *PSA Jour.*, Sec. B., No. 1, vol. 17, pp. 2–6, Feb. 1951.
11. F. C. Williams, "Current problems in the sensitometry of color materials and processes," *Jour. SMPTE*, vol. 56, pp. 1–12, Jan. 1951.
12. J. E. Bates and I. V. Runyan, "Processing control procedures for Ansco Color film," *Jour. SMPE*, vol. 53, pp. 3–24, July 1949.

Proposed American Standard

ALMOST FROM THE OUTSET of the motion picture industry, the size and shape of the 35-mm film perforation presented a continuous and continuing problem. The Proposed American Standard appearing on the following pages is another attempt to standardize a single perforation (Dubray-Howell) for both negative and positive film. However, this is not offered now as a universal perforation to replace the two separate standards but rather as a third and *alternate* cutting and perforating standard. It is again published here for 90-day trial and criticism. All comments should be sent to Henry Kogel, SMPTE Staff Engineer, prior to January 1952 along with a carbon for Dr. E. K. Carver, Chairman of the Film Dimensions Committee.

This proposal and a detailed history of the subject were previously published in April 1949; however, objections were raised and the proposal was rejected by the Standards Committee on the grounds that a 90-day trial period was insufficient for a proposal of this nature. It has since been thrashed out in meetings of the Film Dimensions Committee, changes of a non-dimensional character made, and all objections overcome. Since a period of well over two years has elapsed, it is believed that a 90-day period, subsequent to this publication, should be adequate for comment.

A brief review of the sprocket-hole story is provided for background information.

The first attempt at standardization was initiated with a paper by D. J. Bell, published in the JOURNAL for October 1916. He proposed a perforation having a width of 0.110 in., a height of 0.073 in. and rounded sides. Within a few years, this "Bell & Howell" perforation was accepted almost universally and was formally standardized in 1922. This development led in turn to a redesign of sprocket teeth to provide a greater picture steadiness with the accepted perforation.

However, after some time, it was noted that this perforation gave evidence of fracturing at the corners when run frequently through projection equipment. In 1923, (on the basis of experimental tests) J. G. Jones proposed a rectangular perforation having filleted corners, the same 0.110-in. width and an increased height, 0.078 in., to eliminate sprocket-tooth interference encountered previously with the 0.073-in. dimension. Since this new perforation might have given trouble in some cameras then in use, its use was not recommended for negative films. With its adoption in October 1925, separate standards for positive and negative film came into existence.

The present proposal was first put forth by Messrs. Dubray and Howell in April 1932. They claimed that it combined the advantages of both perforations and that film so perforated could still be used on all existing equipment without alteration. This, however, found few supporters at the time and instead the existing rectangular perforation for positive film was adopted in 1933 as the universal standard for both negative and positive film. Although this standard was used for positive and sound film, it was not used for camera negative film.

In 1937 the Subcommittee on Film Perforating Standards proposed withdrawal of the 1933 standard and adoption of the Dubray-Howell proposal in its place—but without success.

It then became apparent that establishing a universal perforation would be very difficult. This left negative film without an official standard and consequently the old Bell & Howell perforation, still in common use, was re-established as a standard for negative film.

The issue lay dormant until some time in 1945 when the American Standards Association asked the Society of Motion Picture Engineers to reaffirm or revise the standards, in accordance with its policy of periodic review of all standards. In the reviewing process the Motion Picture Research Council refused to approve the negative perforating standard and instead proposed that the whole question be reinvestigated and the Dubray-Howell perforation be reconsidered. The Film Dimensions Committee, therefore, initiated and carried through a rather thorough study of the whole question during 1947–48. The study revealed that this perforation had a projection life superior to the negative perforation and only slightly less than the positive perforation. In addition, it operated satisfactorily in most equipment designed for either of the old perforations and also produced films of satisfactory steadiness. (For additional information on the studies of the Dubray-Howell perforations made by the Motion Picture Research Council, see the January 1951 *Journal*, p. 30.)

At about this time, the registration problem that exists in the printing of certain types of color release prints enters the picture. It is possible to solve the problem by the use of cine negative perforations in the release prints, but then shortened projection life becomes a factor. Meanwhile, two producers used film having the Dubray-Howell perforation for a number of color release prints and obtained very satisfactory results when printing from standard negative Bell & Howell perforations. This lent added weight and significance to the attempts to standardize the Dubray-Howell perforation and, indeed, was the stated reason for the publication of this standard initially in April 1949.

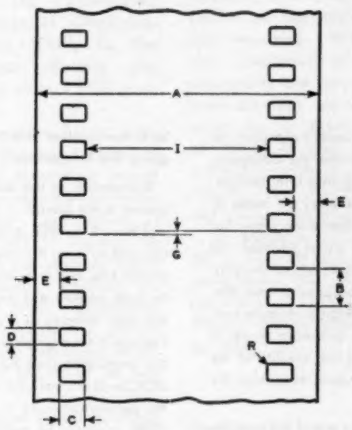
In December 1949 Ansco proposed another type of perforation which they believed might be superior to the Dubray-Howell. This is essentially the negative perforation but with fillets in the previously sharp corners to provide additional strength. The Film Dimensions Committee agreed to wait six to eight months while Ansco conducted their tests and to then review all the experimental evidence. This was done at a subsequent meeting in October 1950. The comparison of the Dubray-Howell and "modified negative" showed little difference as to camera steadiness but definite superiority with the latter in printing. The tests on projection life were not complete but in all cases the modified negative was never worse than the Dubray-Howell. (For a more complete history on the Ansco proposal see the W. G. Hill paper in the August 1951 *Journal*, p. 108.)

The Film Dimensions Committee recommends preliminary publication of the Dubray-Howell proposal at this time, under the belief that: (1) it is not advisable to delay action until final proof is at hand as to the best type of perforation. and (2) the present wide use of the Dubray-Howell perforation means that it is probably here to stay for some time. The proposal is labelled "an alternate standard" in view of the continued usefulness of the present standards and the possibility of a fourth standard becoming the ultimate universal single standard.

Proposed American Standard

Cutting and Perforating Dimensions for 35-Mm Motion Picture Film - Alternate Standards for Either Positive or Negative Raw Stock

PH 22.1



Dimensions	Inches	Millimeters
A	1.377 ± 0.001	34.980 ± 0.025
B	0.1870 ± 0.0005	4.750 ± 0.013
C	0.1100 ± 0.0004	2.794 ± 0.01
D	0.0730 ± 0.0004	1.85 ± 0.01
E	0.079 ± 0.002	2.01 ± 0.05
G	Not > 0.001	Not > 0.025
I	0.999 ± 0.002	25.37 ± 0.05
L*	18.700 ± 0.015	474.98 ± 0.38
R	0.013 ± 0.001	0.330 ± 0.025

These dimensions and tolerances apply to the material immediately after cutting and perforating.

* This dimension represents the length of any 100 consecutive perforation intervals.

NOT APPROVED

Proposed American Standard

Cutting and Perforating Dimensions for 35-Mm Motion Picture Film - Alternate Standards for Either Positive or Negative Raw Stock

PH 22.1

Appendix

The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but owing to the fact that film is a plastic material, the dimensions of the slit and perforated film never agree exactly with the dimensions of the punches and dies. Shrinkage of the film, due to change in moisture content or loss of residual solvents, invariably results in a change in these dimensions during the life of the film. This change is generally uniform throughout the roll.

The uniformity of perforation is one of the most important of the variables affecting steadiness of projection.

Variations in pitch from roll to roll are of little significance compared to variations from one sprocket hole to the next. Actually, it is the maximum variation from one sprocket hole to the next within any small group that is important.

Perforations of this size and shape were first described in the Journal of the SMPE in 1932 by Dubray and Howell. In 1937, a subcommittee report reviewed the work to date. The main interest in the perforation at that time was in its use as a universal perforation for both positive and negative film. The perforation has been adopted as a standard at this time largely because it has a projection life comparable to that of the perforation used for ordinary cine positive film (Z22.36–1947), and the same over-all dimensions as the perforations used in the negative film (Z22.34–1949). It should be particularly noted that although the present standard has the same over-all dimensions as the older cine negative perforation, positioning pins or sprocket teeth made to fit this perforation exactly will injure the corners of the cine negative perforation.

NOT APPROVED

Engineering Activities

PH22

A meeting of ASA Sectional Committee PH22, chaired by J. A. Maurer, was held May 2, 1951. The Chairman noted that for the last several years the function of PH22 has been primarily one of formally validating proposed standards already thoroughly reviewed by several SMPTE Committees. However, the forthcoming meeting of the International Organization for Standardization (ISO) in the United States sometime during the summer of 1952 requires that PH22 play a more fundamental role.

ISO's Technical Committee 36 on Cinematography (ISO/TC 36) was formed in 1948 for the purpose of preparing world standards in the field of cinematography. The secretariat for this Committee is assigned to the ASA, which means, in effect, that PH22 is given the responsibility for technical developments leading to world standards in this field. However, outside of a limited exchange of correspondence, no formal action has been taken and no formal meeting of ISO/TC 36 has ever been held.

It has been suggested that a first meeting of ISO/TC 36 should be held in the United States some time during the summer of 1952—probably in New York City. The technical responsibility for formulating an agenda for this meeting belongs to PH22, and since this agenda must be determined six months in advance of the meeting date, negotiations leading to its determination must be concluded by the end of this year. In order to get things started, Mr. Maurer advised that he, in cooperation with SMPTE Engineering Vice-President F. T. Bowditch, had reviewed all current American Standards and recent proposed standards, and that these had been referred to the appropriate SMPTE Engineering Committees and to the Motion Picture Research Council with the request that a definite recommendation with respect to international standardization be submitted in each case, together with reasons for such recommendations.

In the discussion the question was raised as to whether the agenda for this first meeting should include all possible standards or only the most important ones. It was finally agreed that the agenda should be confined to the most essential matters, leaving simply as "not proposed" those present standards considered either not suitable or not important.

As a matter of procedure in defining the agenda, it was agreed that a formal letter ballot of the entire PH22 Committee is not required. When the SMPTE notifies the Chairman of PH22 that a group of standards has been considered suitable for consideration as world standards, he will send out a letter notifying the members of PH22 of this recommendation, giving a limited period of, say, two weeks during which any member may register any objections he may have.

In addition to the discussion on ISO/TC 36, a limited discussion took place on the procedure for review of foreign draft standards. The newly defined scope of PH22, was endorsed by the Committee as read.

Optics

The Optics Committee met on May 3, 1951, under the Chairmanship of R. Kingslake. Two subjects were discussed at this meeting: (a) the Proposed Standard for Lens Aperture Calibration and (b) the general problem of standards for 8-mm, 16-mm and 35-mm projection lenses.

The lens aperture calibration proposal was discussed in detail and a new draft drawn up. (This proposal will appear in the October 1951 *Journal*.)

The only current standard for projection lenses is the standard for the mount of a projection lens for 16-mm projectors using a 2.062-in. barrel, established by Committee Z52 during the war and reprinted in JAN-P-49. This lacks a few detailed specifications and will be redrawn by the Optics Committee. The Committee agreed that similar specifications should be set up for home 8-mm and 16-mm projectors. Dr. Pestrecov and Mr. Maulbetsch were asked to draw up similar outline limitations for two sizes of 35-mm

projection lenses. These will then be sent to all projector and lens manufacturers for comment.

Film Projection Practice

This Committee held its first meeting under its new Chairman, M. D. O'Brien, on May 3, 1951. Past activity and inactivity were discussed and plans made for future action. Specific issues tackled were:

1. Projection-Room Plans. This is to be reviewed and revised by a task group of three and prepared for *Journal* publication.

2. Projection-Room Maintenance Instructions. The advisability of this project was questioned and the Chairman is to give it further study.

3. Lamp-Mounting Dimensions. The need for standardization was emphasized and a survey on existing equipment proposed. Mr. Davee accepted responsibility for the initial phase of this project.

4. Review of Standards. Two Standards, PH22.28 and PH22.58, were studied as potential International Standards but rejected on the grounds that they required revision. Messrs. Schlanger and Todd agreed to draw up a new draft of PH22.28. The Committee did not wish to overextend its initial activity and, therefore, relegated revision of PH22.58 for future action. Review of PH22.4 was on the agenda but was also tabled for future consideration.

Films for Television Committee

The emulsion position of 16-mm film (toward screen or lens) has been a vexing problem for some time and it was again reviewed at the May 2, 1951, meeting of this Committee. Dr. Garman, the Chairman, stated that he had received a good deal of correspondence on this question and that it might be helpful if someone would abstract the gist of the comments. Mr. Schlafly offered to do this and Messrs. Dewhirst, Misener and Veal proferred additional information to help round out the picture. (A symposium on this topic is to be held at the Society's 70th Convention in Hollywood, October 15–18.)

The new "Society Leader" was also discussed, the Subcommittee chaired by C. L. Townsend having asked the parent Committee for authorization to publish a status report. After making minor amendments, the Committee gave its approval for *Journal* publication. (The report was published in the May 1951 *Journal.*)

In addition, a new Subcommittee was formed, chaired by W. F. Little, dealing with the many problems relating to pictorial quality of television films. The Subcommittee's scope will also include preparation of a glossary of terms peculiar to the subject material studied and a continued consideration of the 30-frame question.—HK.

Atlantic Coast Meeting on Animation

At the March meeting of the Atlantic Coast Section of the SMPTE, Paul Terry of Terrytoons, New Rochelle, N.Y., showed a film describing the making of animated cartoons at his studios and then showed a couple of cartoons that had been featured in the "how-to." Mr. Terry himself supplied the narration. A brief history of animation was presented with appropriate pictures and illustrations.

Since the dawn of man, the artist has been intrigued with the idea of achieving not only a fine record of life and events in a work of art, but also actual records of scenes in motion. The photographer attained motion when the motion picture camera was perfected, but the draughtsman had the difficult handicap of attempting to record a drawing so that it appeared to be an actual movement.

The Stone Age genius who drew the Wild Boar of Altamira in Spain 20,000 years ago, suggested the motion of a running beast by drawing wiggly lines by its legs, exactly as the comic-strip artist renders it today. This represents, perhaps, the very first suggestion of animation. The Egyptian Goddess Isis was painted on each of 110 columns on a temple in 1600 B.C. Each figure was in a progressively changed position so that a dashing charioteer passing by enjoyed an illustion of motion, with these

110 images merging into one dancing figure. The ancient Greeks and Chinese also did much the same thing on vases and scrolls.

Others, including the versatile Leonardo da Vinci, rendered different positions of the human figure, in which several drawings were superimposed on one space, suggesting animation.

Perhaps the first conscious attempt at comical drawings suggesting motion was by a German named Athanasius Kircher who devised the first magic lantern and did two drawings of a mouse crawling into a sleeping man's mouth. This was done in two projections of still drawings, like a comic strip, in 1640.

In 1824, Peter Mark Roget discovered a vital principle of sight. He learned that the eye tends to retain an image it has just seen. If this were not so, motion pictures would be impossible. He built a spinning top that had a bird on one side and a cage on the other. When the top spun, the bird seemed to be in the cage.

William Lincoln patented a device called the Zoetrope in 1867, and this marked the introduction of animated cartoons into this country. It consisted of a wide shallow cylinder, mounted on a stand. The cylinder had a number of spaced slits near the tops and the drawings, made on a strip of paper about two and a half feet long, were inserted on the inside of the cylinder. As the cylinder revolved, one would look through the moving slits and there would be a sense of motion of the slightly different drawings on the strip.

There were many pioneers who struggled, often in vain, to perfect better devices for animation. One even lost his sight as a result of such a striving, and the world is deeply indebted to these great persistent men.

The common "flipper book" was introduced in 1868. It was made up of a pad of drawings bound in book fashion along one edge. The book was held in one hand, along the bound edge, while the other hand flipped the pages. As they slipped from under the thumb, the drawings, all in sequence, passed quickly before the eyes and gave the illusion of continuous motion—the animated cartoon.

The first experimental cartoon was created by a newspaper artist named James Stuart Blocton, encouraged by Thomas A. Edison. He made 3000 drawings of funny faces and jugglers and called it "Humorous Phases of Funny Faces." It was exhibited to the public, which found it hilarious fare in 1906.

To Winsor McCay, another newspaper artist, goes credit for the animated cartoon in the form in which it appears today. In 1909, he made *Gertie, the Dinosaur*, the first complete story-depicting animated cartoon. In all, McCay made ten cartoons, and the work that went into each cartoon was staggering. He drew all the thousands of pictures complete with background scenes in each.

Paul Terry pays the greatest tribute to McCay, not only as the man who inspired him to start his own animated cartoon productions, but as the artist whose knowledge, ability and vision foresaw its tremendous possibilities.

In 1915, Paul Terry, then a newspaper cartoonist, developed the first process for making one background for a scene and doing the animations on celluloid and superimposing them on the backgrounds, thus vastly reducing the labor. In that year, Mr. Terry patented the first double-exposure process. At present he turns out 26 two-reel features a year at his New Rochelle plant.

The development of both music and story ideas which go into Terrytoons was shown in color movies of Mr. Terry's 80-man staff at work. Music and sound-strip come first, even as in *Tales of Hoffman*, then story and pictures are tailored to fit. Rapport exists between composers and writers, however, and the composers do the score with a certain story line in mind. If Mighty Mouse is to kiss his lady, the length of time is estimated before the composer sits down at the piano. A good many motions are rehearsed and clocked on a metronome in these precomposition conferences, and Mr. Terry assured his audience that even a bull being tossed out of an arena can be "seen" and timed by the conferees. This throwing of the bull, however, does not impede production.

In addition to the above report, which was kindly checked by Mr. Terry, we have been able to get the following reference list from Ernest M. Pittaro.

A Reference List on Animation

SMPE Journal Articles

J. A. Norling, "Trick and process cinematography," *Jour. SMPE*, vol. 28, pp. 136–157, Feb. 1937.

J. E. Burks, "A third-dimensional effect in animated cartoons," *Jour. SMPE*, vol. 28, pp. 39–42, Jan. 1937.

E. Theisen, "The history of the animated cartoon," *Jour. SMPE*, vol. 21, pp. 239–249, Sept. 1933.

W. Garity, "The production of animated cartoons," *Jour. SMPE*, vol. 20, pp. 309–322, Apr. 1933.

Magazine Articles

J. Noble, "History of the animated film," *Intern. Phot.*, vol. 21, Pt. I, pp. 13–16, Apr. 1949; Pt. II, pp. 13–16, May 1949.

N. Taylor, "Animated movie making for the beginner," *Home Movies*, Aug. 1946.

H. Black, "Lucite and Lantz came through for the Navy," *Am. Cinemat.*, vol. 26, pp. 372–373, 392, Nov. 1945.

W. Bosco, "Harman unveils new animation unit," *Am. Cinemat.*, vol. 26, pp. 190–191, June, 1945.

A. Wolff, "Simple cartoons," *Movie Makers*, vol. 18, pp. 472, 492–493, Dec. 1943.

C. Randall, "Animation for amateur defense films," *Home Movies*, vol. 9, pp. 185, 206–207, May 1942.

C. Fallberg, "Animated cartoon production today," *Am. Cinemat.*, vol. 23: Pt. I, pp. 151, 188–190, Apr. 1942; Pt. II, pp. 202–203, 232–237, May 1942; Pt. III, pp. 250–251, 282–285, June 1942; Pt. IV, pp. 300–303, 331–332, July 1942; Pt. V, pp. 344–346, 380–382, Aug. 1942.

M. Goldberger, "Making maps move," *Movie Makers*, vol. 11, pp. 479, 489–490, Nov. 1936.

W. Lantz, "Synchronizing sound cartoons," *Am. Cinemat.*, (*Amateur Movie Section*) vol. 16, pp. 76, 82–83, Feb. 1935.

H. Angell, "Animation Advice," *Movie Makers*, vol. 8, pp. 152–153, 170, Apr. 1933.

W. Lantz, "Sound cartoons and 16-mm," *Am. Cinemat.*, vol. 13, pp. 36–37, 41, July 1932.

Books

Raymond Spottiswoode, *Film and Its Techniques*, University of California Press, Los Angeles, 1951, pp. 120–146.

W. Foster, *Animated Cartoons*, Foster Art Service, Inc., Laguna Beach, Calif., 36 pps. Very little text, all drawings and charts for those interested in the drawing phase of animated cartoons. This is an excellent treatment of modern animated cartoon technique.

P. Blair, *Advanced Animation*, Foster Art Service, Inc., Laguna Beach, Calif. This again treats the drawing and cartooning aspect of animation. It is an excellent reference and in constant use by professional animators in the industry but of interest to those looking for information about the drawing of animated cartoons, not their production from a technical standpoint.

J. Battison, *Movies for TV*, Macmillan, New York, 1950. One chapter in which animation comes in for a light lay treatment.

H. Gipson, *Films in Business and Industry*, McGraw-Hill, New York, 1947, 291 pps. Several mentions and many reproductions of various types of animation with chapter on animation. Well worth reading.

A. Epstein, *How to Draw Animated Cartoons*, Greenberg Publishers, 201 E. 57th St., New York, 1945, 64 pp. A superficial treatment of animation from the drawing standpoint.

R. Field, *The Art of Walt Disney*, Macmillan, New York, 1942, 290 pps. Written from the lay viewpoint. Of interest from the drawing standpoint, containing many excellent reproductions of Disney cartoons.

N. Falk, *How to Make Animated Cartoons*, Foundation Books, New York, 1941, 79 pps. A nontechnical treatise of interest to the layman.

E. Lutz, *The Motion Picture Cameraman*, Scribners, New York, 1927, 248 pps. This book is outdated, but has a chapter with interesting information relative to animation.

E. Lutz, *Animated Cartoons*, Scribners, New York, 1926, 261 pps. Although outdated, this book contains some valuable information.

If readers know of additional sources of information about animation, correspondence will be welcomed by Ernest M. Pittaro, 137-65 70th Ave., Flushing, N.Y.

International Commission on Illumination

Among the organizations in which our Society maintains official representation is the United States National Committee of the International Commission on Illumination.

Present SMPTE representatives to the USNC whose terms continue until December 31, 1952, are: Herbert Barnett, General Precision Laboratory; R. E. Farnham, General Electric Co.; and H. E. White, Eastman Kodak Co.

The ICI has these objectives:

1. to provide an International forum for all matters relating to the science and art of illumination;
2. to promote by all appropriate means the study of such matters;
3. to provide for the interchange of information between the different countries; and
4. to agree upon and to publish international recommendations.

"While owing its chief allegiance to this country, the United States National Committee desires to cooperate fully and cordially with the ICI and its other national committees for the promotion of the science and art of illumination and for the establishment of cordial international relations. It is important that those who act for the Committee keep these objectives fully in mind, and diplomatically extend friendly helping hands to other countries without permitting American ideals to be sacrificed or ignored."

During Session XII of the ICI held in Stockholm, Sweden, June 26 to July 7, 1951, Dr. Ward Harrison of the United States was elected president of the Commission for a term ending in 1955.

C. A. Atherton of the United States, long a delegate to the ICI, was elected Honorary Secretary. A paper prepared by Ralph Evans (Eastman Kodak Co.) was presented by Dr. Dean B. Judd of the National Bureau of Standards, because Ralph was unable to attend.

Numerous items on the agenda of Session XII include such matters as definitions of fundamental terms used in the field of illumination and photometry, and standards of luminous intensity and luminous flux. Scotopic luminosity functions for young eyes were discussed and relative luminosity values to be used in determining threshold response were set down at length. In addition, attention was given to such practical matters as highway lighting and automobile headlights. Of particular interest to Society members were the recommendations presented on the subject of theater screen lighting and television. These are quoted in their entirety:

Committee 62d, Screen Lighting in Cinemas

"*1. Screen brightness.* When showing 35-mm film it is recommended that the brightness measured in the middle of the screen shall be 35 (+15–10) nit. Whilst the measurements are being taken, the projector is to be running without film. The arc lamp current desired shall be accurately set, and the arc lamp shall be adjusted to give maximum lighting in the middle of the screen. In the middle of the short side of the screen the brightness must not be below 75% of the value in the middle of the screen.

"*2.* It is further recommended that the Secretariat Committee shall study the question of desirable brightness values for screens less than 3 m or more than 8 m wide.

"*3. Stray light.* The Cinema Lighting Committee draws attention to the French experiments indicating that the screen brightness, due to stray light (measured with the projector running) should not exceed 5% of the value obtained with the projector operating without film in it, and recommends that National Committees should make similar experiments.

"*4. Brightness of Surround.* It is recommended that each country report at the next meeting, information of brightness screen surround, preferably including screen brightness values as well."

Committee 63, Television

"*1.* It is desirable that each interested country, prior to the next session, should propose a report covering lighting developments in the field of black-and-white television (lighting of the studios and for reception).

"*2.* It is suggested that a special subcommittee be appointed to deal with color television.

"*3.* It is desirable to collect information dealing with the ambient lighting used when viewing.

"*4.* It is desirable to propose in collaboration with the transmission authorities, instructions for the use of televiewers, which will enable them to adjust their receivers to give the best reception.

"*5.* It is desirable that a thorough study should be made with the object of improving the quality of films used in television.

"*6.* It is desirable that a study of visual fatigue due to viewing be made in each country in collaboration with the appropriate medical body."

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (H) Fellow (F) Active (M) Associate (A) Student (S)

Apitsch, John W., Sound Engineer, Twentieth Century-Fox Film Corp. **Mail:** 10367 Cheviot Dr., Los Angeles 64, Calif. **(A)**

Bury, John L., Jr., University of Hollywood. **Mail:** 226 Argonne Ave., Long Beach 3, Calif. **(S)**

Demoreuille, Pierre, President, The Carbone Corp. **Mail:** 10 Bowers Rd., Caldwell, N. J. **(M)**

Gramaglia, Albert A., Sound Mixer, RCA Sound Recording Div. **Mail:** 685 E. 237 St., New York 66, N.Y. **(A)**

Haburton, Ralph, Chief, Processing Branch, Motion Picture Section, U.S. Air Force, Wright-Patterson Air Force Base. **Mail:** 1335 Oakdale Ave., Dayton 10, Ohio. **(M)**

Herald, Robert L., 1306 N. Pennsylvania St., Indianapolis, Ind. **(A)**

Hurd, Yorick G., Physicist, Twentieth Century-Fox Film Corp. **Mail:** 228-35 Mentone Ave., Rosedale 10, L.I., N.Y. **(M)**

Kammerer, Guenter, Technician. **Mail:** c/o The Vines, 1208 Drummond St., Montreal, P.Q., Canada. **(A)**

Knutson, N. Theodore, New Product Designer, Bell & Howell Co. **Mail:** 5230 Oakdale Ave., Chicago 41, Ill. **(A)**

Koeber, Henry J., Jr., Design Engineer, Bell & Howell Co. **Mail:** 4144 N. Olcott, Chicago 34, Ill. **(A)**

Lakemacher, Elmer E., Machine Design Engineer, Bell & Howell Co. **Mail:** 3828 N. Kenneth Ave., Chicago 41, Ill. **(A)**

Lewis, David L., Production, 16-Mm Motion Pictures, Northrop Aircraft Co. **Mail:** 3619 Marcia Dr., Los Angeles 26, Calif. **(A)**

Lucas, Robert James, Chief Technician, Metro-Goldwyn-Mayer. **Mail:** 7 Orient St., Gladesville, Sydney, N.S.W., Australia. **(A)**

Mentz, Charles H., Television Engineer, KPIX. **Mail:** 416 Serrano Dr., San Francisco, Calif. **(A)**

Miyamoto, Toshio, Manager, Fukujiro Fukano. **Mail:** 876 Shimokomatsu-Machi, Katsushika-Ku, Tokyo, Japan. **(M)**

Mylander, Karl F., Ohio State University. **Mail:** 331 East Water St., Oak Harbor, Ohio. **(S)**

Nupnau, Arthur, Junior Design Engineer, Bell & Howell Co. **Mail:** 3916 N. Sawyer Ave., Chicago 18, Ill. **(A)**

Oliveri, Paul, Motion Picture Laboratory Technician, U.S. Army Signal Corp. **Mail:** 114-17—128th St., South Ozone Park, N.Y. **(A)**

Poulson, William R., TV Films, 16-Mm Laboratory. **Mail:** 5044 Walmar Ave., La Canada, Calif. **(A)**

Quateman, Joseph, Bell & Howell Co. **Mail:** 2533 Jackson, Evanston, Ill. **(A)**

Roos, Dirk J., Manager, Sound Division, Radio Specialties Co. **Mail:** 34480 Capitol Dr., Plymouth, Mich. **(A)**

Schwartzberg, Henri, Motion Picture Film Buyer, American Theatres Corp. **Mail:** 72 Beaconsfield Rd., Brookline 46, Mass. **(A)**

Seward, Edward, Free-lance Motion Picture Director. **Mail:** 3312—72 St., Jackson Heights, L.I., N.Y. **(M)**

Shimek, John A., Production Engineer, Bell & Howell Co., 1700 McCormick Rd., Chicago 45, Ill. **(A)**

Strang, William C., Specialist, 16-Mm Film Reports, North American Aviation, Inc. **Mail:** 4454 Lakewood Blvd., Long Beach 8, Calif. **(A)**

Thornwald, Everett D., Design Engineer, Bell & Howell Co. **Mail:** 1348½ Estes Ave., Chicago 26, Ill. **(A)**

Vinton, William H., Research Manager, Du Pont Photo Products. **Mail:** Du Pont Club, Parlin, N.J. **(M)**

Wagner, Karl L., Independent Producer. **Mail:** 501 C.C. Bk. Bldg., Des Moines 9, Iowa. **(M)**

Walker, Edwin M., Motion Picture Laboratory Technician, U.S. Air Force, Wright-Patterson Air Force Base. **Mail:** 931 Crestmore Ave., Dayton, Ohio. **(M)**

Weber, John P., Jr., Electronics Design Engineer, Bell & Howell Co. **Mail:** 6440 N. Albany, Chicago 45, Ill. **(M)**

West, John H., In charge, Film Renovating and Treating Laboratory, Rapid Film Technique. **Mail:** 3525—77th St., Jackson Heights, L.I., N.Y. **(M)**

CHANGES IN GRADE

Choudhury, Siraj-ul-Islam, Free-lance Artist, Motion Picture Production, Dept. of State and News of the Day. **Mail:** 235 Eldridge St., New York 2, N.Y. **(S)** to **(A)**

Townsend, Charles L., TV Technical Film Director, National Broadcasting Co. **Mail:** 49 Hillcrest Dr., DuMont, N.J. **(A)** to **(M)**

Vosburgh, Richard V., TV Film Editor and Cameraman, Paramount TV Productions. **Mail:** 5800 Green Oak Dr., Hollywood 28, Calif. **(S)** to **(A)**

DECEASED

Ball, J. Arthur, Consulting Engineer, Color Photography. **Mail:** 12720 Highwood St., Los Angeles 49, Calif. **(F)**

Winter, Ernest A., Service Inspector, Western Electric Co., Ltd. **Mail:** 14 Hawkeshead St., Southport, Lancaster, England. **(A)**

Obituary

J. Arthur Ball died in Los Angeles on August 27 at the age of 57. In recent years he was actively engaged as a color consultant, dividing his time between Los Angeles and New York.

He was an alumnus of Massachusetts Institute of Technology and was long associated with Technicolor, as an executive of Technicolor, Inc., and with its subsidiary, Technicolor Motion Picture Corp. which manufactures the color films. He was Technical Director for Technicolor when the firm made *Becky Sharp*, which was a forerunner of a long line of color motion pictures. In 1938, Mr. Ball was given an Oscar by the Academy of Motion Picture Arts and Sciences for his contributions to color motion pictures. Many of his patents in the field of color photography were assigned to Technicolor for whom he built a camera reported to have cost $15,000 and five months time to make.

As a consultant he had served the Photo Products Dept. of E. I. du Pont de Nemours & Co. since early 1946. During this time he had assisted in the development of Du Pont's recently introduced motion picture color positive film and on other color motion picture products. He was also recently a color consultant for the Springdale Laboratories of Time, Inc., at Stamford, Conn., and for Walt Disney Productions.

Motion pictures in color depend on the engineers' knowledge of the "Principles of Color Sensitometry." A 72-page article bearing that title and prepared by the Color Sensitometry Committee appeared in the *Journal* for June 1950. Attractive reprint copies may be purchased for $1.00.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 32, Apr. 1951

Under Water With the Aquaflex (p. 132) *T. Gabbani*

Editing Magnetic Sound (p. 137) *L. L. Ryder*

Ten Basic Factors of TV Film Production (p. 138) *A. L. Marble*

vol. 32, May 1951

The Westrex Magnetic Film Recording Systems (p. 182) *R. Lawton*

Hollywood Knowhow in TV Film Production (p. 184) *L. Allen*

In the Best Professional Manner (p. 186) *W. Strenge*

vol. 32, June 1951

The Kinevox Synchronous Magnetic Film Recorder (p. 224) *R. Lawton*

Station-Production of TV Motion Pictures (p. 226) *D. L. Conway*

vol. 32, July 1951

Evolution of the Viewfinder Ground Glass (p. 262) *J. V. Noble*

The Stancil-Hoffman Synchronous Magnetic Film Recorder (p. 264) *R. Lawton*

Economical TV Filming (p. 268) *J. H. Battison*

Audio Engineering

vol. 35, Aug. 1951

Efficiency of Direct-Radiator Loudspeakers (p. 13) *V. Salmon*

A New Approach to Loudspeaker Damping (p. 20) *W. Clements*

British Kinematography

vol. 17, Dec. 1950

Practical Applications of Magnetic Re-Recording—Tape and Film, Pt. I, Historical Aspects (p. 182) *K. G. Gould*

Engineering Aspects of Film Production (p. 196) *R. Howard Cricks*

vol. 18, Jan. 1951

Motion Picture Presentation (p. 4) *S. B. Swingler and R. R. E. Pulman*

Technical Objectives in Pre-Planning Production (p. 18) *K. E. Harris*

vol. 18, Feb. 1951

Economic Aspects of Studio Lighting, Pt. I, Series-Parallel Wiring of Arcs (p. 44) *C. W. Hillyer*

Back Projection in the Kinema (p. 56) *J. L. Stableford*

vol. 19, July 1951

Presidential Address (The Motion Picture Industry) (p. 13) *L. Knopp*

The Magnetic Recording and Reproducing Equipment for the Telekinema (p. 19) *G. F. Dutton*

Electronics

vol. 24, May 1951

Constructing the Tricolor Picture Tube (p. 86)

vol. 24, July 1951

Continuous Film Scanner for TV (p. 114)

vol. 24, Aug. 1951

Plans for Compatible Color Television (p. 90)

Picture Generator for Color Television (p. 116) *R. P. Burr, W. R. Stone and R. O. Noyer*

General Electric Review

vol. 54, June 1951

Spectrum Utilization in Color Television (p. 18) *R. B. Dome*

vol. 54, July 1951

Over-Age Lamps May Mar Television Reception (p. 42) *J. H. Campbell and H. E. Schultz*

Ideal Kinema

vol. 17, May 17, 1951

Projection Equipment in the Telekinema (p. 7) *R. H. Cricks*

Televised Pictures on Large Screen (p. 9)

International Projectionist

vol. 26, Apr. 1951

Honeycomb-Condenser Lamp Optics (p. 5) *A. R. Schultze*

Evaluating the Honeycomb-Condenser Lamp (p. 6) *R. A. Mitchell*

Comparative Data Anent Nitrate Safety Film (p. 13)

Theater Television via the RCA PT-100 Equipment, Pt. V, Projectionist Operating Procedure (p. 18) *RCA Service Co., Technical Products Division*

vol. 26, May 1951

The Magic of Color (p. 13) *R. A. Mitchell*

Theater Television Via the RCA PT-100 Equipment, Pt. VI, Interpretation of Image Characteristics (p. 18)

vol. 26, June 1951

Lens-Correction: What it Means (p. 5) *A. E. Murray*

GPL's New 16-Mm Sprocket Intermittent (p. 20)

vol. 26, July 1951

The Magic of Color (p. 5) *R. A. Mitchell*

Motion Picture Herald

vol. 183, Pt. 2 (Better Theatres), June 2, 1951

Changing to Faster Lenses Can Increase Screen Light (p. 31) *G. Gagliardi*

Radio & Television News

vol. 46, July 1951

Practical Sound Engineering, Pt. V, A Brief History of Early Experiments in Reproducing Sound as Compared With Modern Systems (p. 60) *H. M. Tremaine*

The Problem of Recording TV Frequencies (p. 16) *J. D. Goodell*

vol. 46, Aug. 1951

TV Pictures in Color (p. 38) *N. Chalfin*

Tele-Tech

vol. 10, June 1951

Television Films Adapt TV Techniques (p. 38) *J. H. Battison*

vol. 10, July 1951

Latest Color Television Developments (p. 28)

Your Journals bound make a valuable permanent reference. Six issues constitute a Volume and should be bound with the special contents page (supplied beginning with Vol. 56) and index furnished with each June and December issue. For details of binding see page 702 of the June 1951 *Journal*.

Journal indexes covering the thirty-four years from 1916 through 1950 may be purchased from Society Headquarters.

1916–1930 $1.25 1930–1935 $1.25 1936–1945 $2.00 1946–1950 $1.50

American Standards form the technical foundation for motion pictures around the world. All current standards were listed by subject and by number in the *Journal* Index 1946–1950. Reprint copies of this list, which includes all previous *Journal* references to each standard, are available from Society Headquarters without charge.

Complete sets of all sixty current standards in a heavy three-post binder with the index are $13.50, plus 3% sales tax for purchases within New York City, and are available from Society Headquarters. Single copies of any particular standard must be ordered from the American Standards Association, 70 East 45th St., New York 17, N.Y.

Test films are the customary tool for checking picture and sound performance in theaters, service shops, in factories and in television stations. Twenty-seven different test films in 16- and 35-mm sizes are produced by the Society and the Motion Picture Research Council. Write to Society Headquarters for a free catalog.

Meetings of Other Societies

Theatre Equipment and Supply Manufacturers' Association (in conjunction with Theatre Equipment Dealers), Oct. 11–13, Ambassador Hotel, Los Angeles, Calif.

National Electronics Conference, Seventh Annual Conference, Oct. 22–24, Edgewater Beach Hotel, Chicago. The conference is sponsored by the American Institute of Electrical Engineers, Institute of Radio Engineers, Illinois Institute of Technology, Northwestern University and the University of Illinois, with participation by the University of Wisconsin and the Society of Motion Picture and Television Engineers.

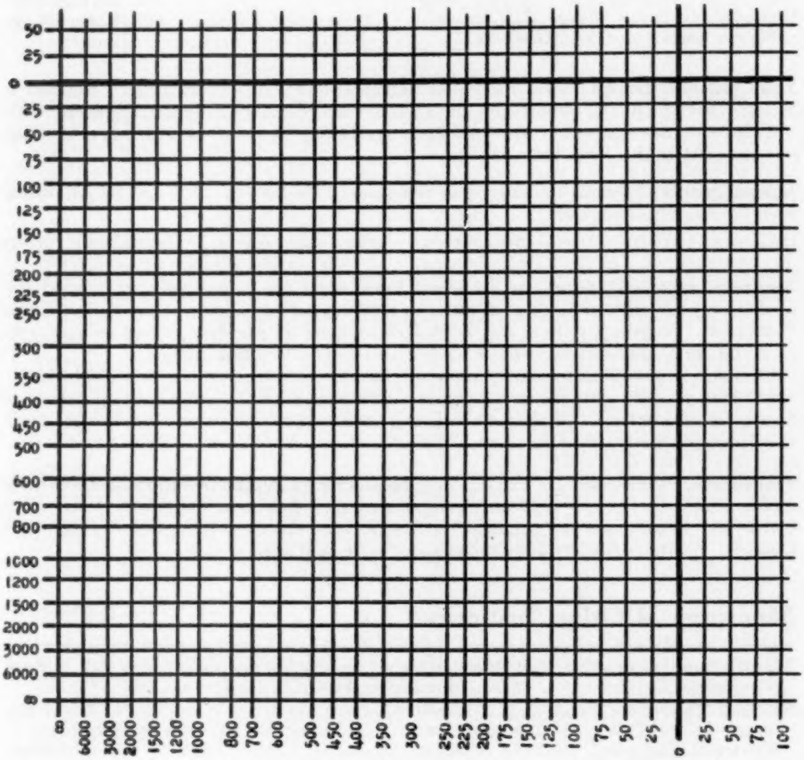
The American Institute of Physics is holding a twentieth anniversary meeting in Chicago on October 23–27. Its member societies will hold meetings at that time as follows:

Acoustical Society of America, Oct. 23–25
Optical Society of America, Oct. 23–25
Society of Rheology, Oct. 24–26
American Physical Society, Oct. 25–27
American Association of Physics Teachers, Oct. 25–27

New Products

Further information about these items can be obtained from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of news items does not constitute an endorsement.

Dylewski ARKTAN is arctangent coordinate graph paper available as $8\frac{1}{2} \times 11$ in. tracing paper at $1.00 per package of 20 sheets from Orbit Electric Co., 2710 N. Menard Ave., Chicago 39. Available at no charge are samples of the paper and a bulletin describing the paper's use for curve plotting in scientific, mathematical, engineering or statistical analysis. There are two forms: No. 1235 has one arctangent scale and one linear scale; No. 1236 (a portion of which is illustrated below) has double arctangent coordinates.



Erratum

The Utiliscope, the closed-circuit television system that was described in the July 1951 *Journal*, is made by the Diamond Power Specialty Corp. in Lancaster, *Ohio*, not in Lancaster, *Pennsylvania*, as erroneously cited in the *Journal*. This is the industrial television system that has been receiving a good deal of attention in the press because of the wide variety of applications reported, including use in motion picture production.

Society of Motion Picture and Television Engineers

40 West 40th Street, New York 18, N.Y. Tel. LOngacre 5-0172
Boyce Nemec, *Executive Secretary*

Sustaining Members

OF THE

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Altec Companies
Ansco
Audio Productions, Inc.
Bausch & Lomb Optical Co.
Bell & Howell Company
Bijou Amusement Company
J. E. Brulatour, Inc.
Buensod-Stacey, Inc.
Burnett-Timken Research Laboratories
Byron, Inc.
The Calvin Company
Cinecolor Corporation
Cineffects, Inc.
Geo. W. Colburn Laboratory, Inc.
Consolidated Film Industries
Helene Curtis Industries, Inc., Natco Division
DeLuxe Laboratories, Inc.
Du-Art Film Laboratories, Inc.
E. I. du Pont de Nemours & Co., Inc.
Eastman Kodak Company
Fabian Theatres
Max Factor, Inc.
Fordel Film Laboratories
General Electric Company
General Precision Equipment Corp.
- Ampro Corporation
- Askania Regulator Company
- General Precision Laboratory, Inc.
- The Hertner Electric Company
- International Projector Corporation
- J. E. McAuley Mfg. Co.
- National Theatre Supply
- The Strong Electric Co.

Guffanti Film Laboratories, Inc.
Hunt's Theatres
Industrial Development Engineering Associates, Inc.
The Jam Handy Organization, Inc.
Kollmorgen Optical Corporation
March of Time
J. A. Maurer, Inc.
Mole-Richardson Co.
Motiograph, Inc.
Motion Picture Association of America, Inc.
- Allied Artists Productions, Inc.
- Columbia Pictures Corp.
- Loew's, Inc.
- Paramount Pictures Corporation
- Republic Pictures Corp.
- RKO Radio Pictures, Inc.
- Twentieth Century-Fox Film Corp.
- Universal Pictures Company, Inc.
- Warner Bros. Pictures, Inc.

Movielab Film Laboratories, Inc.
National Carbon
National Cine Equipment, Inc.
National Screen Service Corporation
National Theaters Amusement Co., Inc.
Neighborhood Theatre, Inc.
Neumade Products Corp.
Projection Optics Co., Inc.
Radio Corporation of America, RCA Victor Division
Reeves Sound Studios, Inc.
SRT Television Studios
Shelly Films Limited
Technicolor Motion Picture Corp.
Terrytoons, Inc.
Theatre Holding Corporation
Theatre Owners of America, Inc.
Titra Film Laboratories, Inc.
United Amusement Corp., Ltd.
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.